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No. 22

MODERN FLEETS

AND

COMPASS DISTURBANCES IN IRON SHIPS

BUREAU OF NAVIGATION

NAVY DEPARTMENT

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MODERN FLEETS.

BY

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COMPASS DISTURBANCES IN IRON SHIPS.

LECTURE DELIVERED AT THE U. S. NAVAL WAR COLLEGE, SEPTEMBER, 1886, BY

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THE INTERIOR ECONOMY OF A MODERN FLEET.

By Commander CHARLES CAMPBELL, R. N.

INTRODUCTION.

The title of this paper embraces a subject to which it would be impossible to do justice in the time at my disposal. I shall therefore confine myself to a few suggestions with a view to gain in discussion the valuable opinions of the members who have done me the honor of attending.

The revolutionary state of things which is going on in everything connected with a floating fight has again and again been pointed out both at this institution and elsewhere. What was good and proper yesterday is obsolete and condemned to-day; and who knows that to-morrow may not call into existence some new subaqueous or aërial machine which will make it absolutely necessary to build ships that will float bottom upwards, or on some other system contrary to the patterns in office. I fully agree with Capt. R. H. Harris, in his lately published essay,[1] where he states that "he errs not when he predicts that the immediate future will see far greater and more astonishing changes than any of those which he had so summarily discussed."

Under these circumstances, in regulating the interior economy of present and future divisions, squadrons, or fleets, we must strive our utmost not only to "keep pace with the inventions of the day and ahead of all maritime powers," but to organize and exercise in keeping with adopted inventions, so as to be able to use them with greater effect in action than any maritime power; and above all, when anything connected with the fighting capabilities, propulsion, or exercise of the units or their component parts is condemned and proved to be bad, root it out and have done with it.

In a former paper on "The Interior Economy of a Modern Man-of-War,"[2] I gave the detail of what then took place from day to day in a fleet ship, the discipline, distribution of responsibility, and a short review of the changing drills and exercises.

I now propose to follow up that paper and endeavor to show how the coming units of a naval force may be organized, exercised, and massed

[1] See Journal of the Institution, No. 134. [2] Journal, No. 119.

together so as to develop to the very utmost extent their offensive and defensive powers.

In dealing with the past and present I have only endeavored to be accurate, and in suggesting the possible composition and routine of the future I will limit myself to the proposal of plans which are daily and hourly forcing themselves on those whose business it is to prepare the royal and mercantile navy for the strain which must be put upon it in the event of an outbreak of war with powerful naval nations, when it would undoubtedly be called upon to capture or destroy the enemy's ships of war, blockade his ports, ruin his trade in all parts of the world, at the same time protecting our own trade routes, making quite sure of our own food supply, and last, but not least, by finding and attacking the force he might succeed in getting to sea, rendering it quite impossible that any part of our imperial coast should be subjected to the ordeal of foreign attack.

I will not further enlarge on these duties or on the thousands of reasons there are which make "unmistakable naval supremacy" of paramount importance in this country; but I will refer to Admiral P. H. Colomb's Gold Medal Essay,[1] and to Lord Brassey, volume 1, chapter I, where they are described at greater length than I have space for, and with greater force than I can bring to bear, but with whom I most cordially agree.

That these important duties necessitate a large naval force must be patent to all. Still there is a great deal to be done by the careful organization of existing ships, and a systematic arrangement of the component parts of the several classes of royal and mercantile vessels which will assist in carrying out the various operations.

I do not propose to enter into the question of building fleet ships; but I will endeavor to give the detail of a scheme by which we may make the most of what we already have built, are building, and shall build in the ordinary course. Even if the purse at the constructor's disposal were more elastic, the difficulty in the building of fleet ships would still be "how to employ it." The pioneers of naval prediction even now go so far as to say that "the days of the powerful ironclad are numbered;" and without following them to that conclusion, I hold that more large and costly ships of any type, however good, than you can officer, man, or maneuver, may prove a grave error in judgment, and cause the expenditure of funds which are badly needed to bring the adjuncts and auxiliaries to the proportion which has shown itself to be necessary in the composition of the base unit of future fleets. It must also be borne in mind that though it is probable that ships will destroy each other more frequently than in the sailing days, still I venture to hope that we may count upon capturing a few any way, to replace those which may be blown up or rammed; and besides, the extreme longevity of ships, boilers, and machinery will render the building of fleet ships

[1] Journal, No. 94.

less frequent when we have a sufficient number ready to fill their places in a definitely organized scheme of fleet strength.

We are assured both on foreign and home authority that the microbe is to eat away the mammoth from off the seas. But I am inclined to think that it will be some years yet before the microbe can act without the mammoth as a base.

As long as you have to carry monster guns to attack forts and shell arsenals, so long you must have monster carriages in which to transport them; so that the action of the microbe and the mammoth must be blended for mutual support in the unit, division, squadron, and fleet of the future.

In my opinion, the numerical strength of a naval force is not of so vital importance as its unity, flexibility, mobility, organization, efficiency, and the tactical skill of its admirals, commodores, and captains; the absolute certainty of its coal and store supply, and the systematic arrangement of its adjuncts, auxiliaries, reserves, and repairing resources; and it is owing to this conviction that I have prepared this paper in order to lay before the members of this institution the result of my exceptional experience in flagships, together with the changes and additions which that experience has led me to believe are necessary in the composition, routine, and exercise; dealing entirely with what we have or shall have in the immediate future, and referring to matters with which you are all familiar.

As far back as 1872 the necessity for adjuncts to the line-of-battle ship of that day and of the then future was forcibly impressed on my mind, as will be sho vn by the following extracts from an essay written in that year for the Junior Naval Professional Association, and published in the "Gun, Ram, and Torpedo," third essay, chapter five, pages 37, 38.

(1) "The line-of-battle ship should be fitted with means of defense against torpedoes," etc.

(2) "Every fighting ship should be fitted with two very fast steam torpedo quarter-boats," etc.

(3) "Every fighting line-of-battle ship, should have a torpedo tender, a vessel of two to four hundred tons, in which nothing but speed and turning power and torpedo fittings have been considered," etc.

(4) "As regards the defense of the line-of-battle ship, it would be the duty of the small steamers to keep boats from coming too close."

(5) "It is difficult to say how useful these boats may prove. My impression is that they would be invaluable and most destructive to the enemy. The hotter the action and the greater the confusion, the more it would be necessary to use the small boats, and in the hands of cool and practiced officers there is no saying the mischief they might not do," etc.

Fifteen years have elapsed since the above paragraphs were written, mostly spent in the flagships of the Flying, Channel, and Mediterranean

Squadrons, where I have been enabled to witness their gradual development, which has now reached a point where, it seems to me, a systematic organization somewhat on the lines proposed in this paper (or on some probably better ones suggested in discussion) has become of vital importance.

The same idea was brought prominently forward in 1876 by Sir N. Barnaby at the Institution of Naval Architects, who was quoted in this theater by Commander Gallwey in his paper on "The Use of Torpedoes in War," where he states that "it was approved by the highest authorities and variously quoted as an indispensable necessity for a modern fleet of ironclads." And in discussing that paper Captain FitzGerald made out a strong case favor of exercising with adjuncts and auxiliaries where he states: "It appears to me that a squadron conducted on the principle of our present ironclad squadrons, simply by themselves, exercising with masts and sails, etc., does not represent the real study of the science of the art of war. A squadron of ironclads alone no more represents a fighting fleet than a large mass of heavy cavalry would represent an army, without artillery, infantry, engineers, telegraph corps, commissariat, and the other branches which are absolutely necessary to it," etc.

Moreover, practically the torpedo flotilla under my command at Milford last year was much impeded and warded off by the first-class boats of the Channel Squadron.

I therefore disclaim any pretension to create new theories, or to lay down any system of attack or defense, but only to prepare, organize, and exercise on practical lines which appear to me best suited to the ever-changing times.

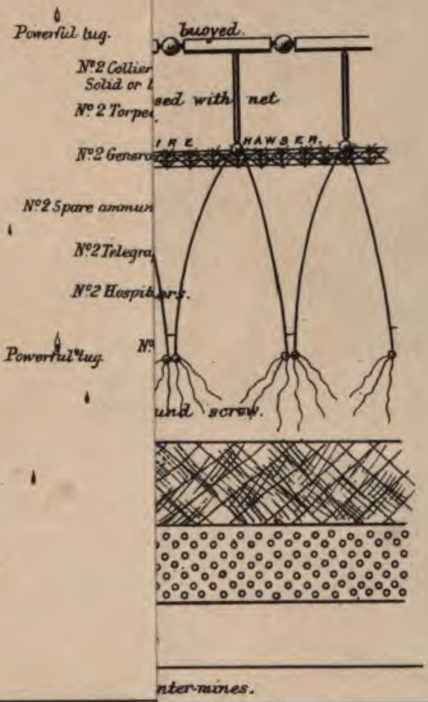
IMPERIAL ORGANIZATION OF THE NAVY.

There is a tendency to speak of the British fleet as a whole. This is quite wrong and misleading, and I for one should like to see the practice discontinued. The talented author of "The Great Naval War, 1887," sends *the* fleet on a wild-goose chase, and leaves the country rather at the mercy of the foe. In a great naval war there probably would be a particular command upon which the country would place greater reliance than on the remainder, but it should be outside and independent of the force for the safe protection of our shores. Both in the past and present we have always had numerous bodies of ships, sometimes called squadrons, sometimes fleets, which composed the navy; so that without proposing any radical change, I may suggest that we should have a definite number of divisions and squadrons, and one or two fleets, "fixed and fitted for use," their nomenclature depending on their numerical strength in units. Thus, as hereafter explained, a division would consist of three units, under a rear-admiral or commodore; a squadron, six units, under a senior rear or vice admiral; and a fleet, twelve units, under an admiral; each unit, division, squadron, or fleet

ROPOSED BOOM.

VITH TORPEDO NETS LACED TO THEM.

SERVATIONS AND CONTACT.



nter-mines.

having its told-off adjuncts and auxiliaries as shown in the diagrams, and a distinct letter, number, or other designating sign of its own, which should be carried by all the component parts belonging to it.

The imperial organization of the navy might then consist of the following as a minimum of what should be absolutely ready, prepared in every detail for a sudden declaration of war:

A. Commissioned reserve, two squadrons, fleet of	12
B. Mediterranean, squadron and division	9
C. Channel, squadron	6
First-class mastless rams	27
D. West Indies, squadron	6
E. Pacific, division	3
F. Australian, division	3
G. East Indies, division	3
H. China, squadron and division	9
I. Southeast coast of America, unit	1
K. Cape and West Coast, division	3
First and second class iron-clads or cruisers, as most suitable	28

L. First and second class cruisers.
M. Armed merchant steamers.
N. Convoy.
O. Obsolete for sacrificing.
P. First-class laid-up reserve, ready for sea, 1 to every division afloat.
Q. Building.
R. Remainder in reserve.
S. Imperial troop ships.
T. Transports on hire.
V. Ocean volunteer ships.
X.
Y. Colonial force.

COMPOSITION AND EXERCISE, PAST AND PRESENT.

Speaking of the fleets and squadrons of the past, they consisted, as everybody knows, of a certain number of line of-battle ships, fire and store ships, with a proportion of frigates for lookout and outside work.

Their whole business in action, besides loading and firing, consisted in the management of the sails, shifting damaged spars, and repairing damaged rigging, thereby giving their exercises aloft a vital importance, which the introduction of steam as a motive power lessened very considerably, and the absence of yards and sails has now done away with altogether.

As their very existence depended on their smartness aloft, regular and systematic drills were organized, taking place every evening at sea, and on especially told-off forenoons in harbor; and these drills were very naturally considered, as far as the fighting power of the fleet was concerned, to equal, if not to exceed, in importance the gunnery exercises.

We read of the ships composing the Mediterranean fleet in harbor, thinking nothing of "in boom-boats," "striking lower yards and topmasts," "run in lower-deck guns," every evening; "crossing royal yards," "out boom-boats," and "run out lower-deck guns" at 8 a. m.

This was merely the morning and evening evolution, besides the usual routine, and at sea-keeping stations, and the necessary shortening or making sail, reefing, tacking, or wearing, all of which was gradually perfecting the fighting powers of the ships, developing the muscles of the ships' companies, and with the cleaning of the ship and boats very properly taking up the greater part of the time of the officers and men.

What I wish particularly to call your attention to is that though these old drills and exercises are obsolete and of no possible use to the development of the fighting power of any ship, they are kept up with the same exactitude and earnestness as though the fate of the ship still depended upon them.

At the same time innumerable new duties have sprung into existence, and systematic instruction in subjects little dreamed of by our forefathers has become imperative. Constant additions are gradually being made to the fleet routine, and little or nothing is condemned and rooted out.

"Look alive and get the main-topsail shifted, so as to rig the boats for countermining before dinner," and "Get the torpedoes ready for running in the afternoon." "Mind and unrig net defense in time to have the top-gallant masts and yards ready for the 8 o'clock evolution." It would never do to hoist the colors without "the royal yards across, and the sails must be loosed to dry, and remember to have the 200 men for musketry at the range by 9, and the submarine mining class at the stores, and the steamboats for tactics, and the divisional drills, especially the newly raised and backward men aloft, and furl sails at 11," and so on *ad lib.*, the new treading on the heels of the old with unceasing energy, while the old clings to the service with a grip that seems as yet unshaken.

In 1882 I gave in this theater the detail of the then existing routine of a fleet ship, which still holds good, and has been reprinted for the illustration of this paper; and I entered fully into the question of Masted *v.* Mastless Iron-clads, maintaining that we ought to try and keep up exercise aloft as long as we had to man sailing cruisers, and I argued that where large bodies of men are to be confined on board mastless ships a substitute for exercise aloft must be found in some form or another.

Since then I have had the honor of serving as second in command for over three years in a masted iron-clad, where the exercise aloft had to be kept up to the letter, sometimes short-handed, our marines being some months at Suakin, and four lieutenants and the greater part of the captains of tops and upper yardmen being up the Nile for a considerable period.

In addition, the want of new drills was felt to a greater extent every day, and they were introduced; the result being that I had the convic-

tion forced upon me that the time had come when yards, sails, and drill aloft must go for good and all in a fleet ship.

And why? Not on account of any question as to propulsion; not because there is a predominating opinion against the necessity for this particular kind of gymnasium; not because the yards and rigging would be most frightfully in the way in action. All of these are good enough reasons in themselves; but because the whole energy and time of the officers and men of a fleet ship must be entirely devoted to the gun, ram, and torpedo, to submarine mining and subaqueous machines, and to the minor training in detail for personal attack and defense, besides the maintenance of the cleanliness and smart appearance of the ship and boats, which, owing to the increase in the cleaning area of the former, and numbers, size, and care required for the latter, together with the reduction in complement caused by the decreased numerical armament, and increased facilities for loading, training, etc., has become a serious nut for the second in command to crack. If the proposed routine be carried out, and the ship kept clean and smart as an efficient fighting base, there will be plenty to employ all hands without sail drill.

Such is pretty nearly the state of things up to date, but every day brings us nearer to the inevitable mastless fleet ship. Already the rapid change in the composition of the force in the Mediterranean is most marked, and it is satisfactory to note the gradual relief of the masted ironclads, and to consider the tactical power of the *Dreadnought*, *Agamemnon*, *Colossus*, *Thunderer*, *Polyphemus*, etc., a powerful base in themselves, with a very large body of trained officers and men. It is for them and for similar vessels that I have ventured to draw out the routine for discussion to-day.

In the Channel we have trained officers and men, but at present no mastless fleet ship.

There may still be a few of my brother officers who cling to the idea that the police work can be done more economically under sail in peace time, and that consequently drill aloft should continue wherever possible; but I should be very much surprised to find one who did not hold the opinion "that in a fleet ship they are simply sinful," and I do not hesitate to add "impossible."

THE COMPOSITION OF THE FUTURE.

As long as a fleet could be considered efficient where the ship proper, with her complement of boats hoisted up and inboard, was the unit, there was more elasticity with reference to its size and power, which could be augmented or diminished at will by simply adding or taking away a ship. And the only question was the getting together of so many vessels, with their guns and rams, to form a fighting fleet.

But every day the reasons for adjuncts and auxiliaries are forcing themselves upon us, and their existence renders a new and systematic

composition imperative; and this composition must be considered and organized, both for war and for peace; first for war, as we exist for no other purpose than to be so ready that peace shall be secured; and, secondly, for peace, as there is nothing gained by wearing out the material, as long as you be certain that it is there handy for war.

I propose to-day to deal with the composition of a fleet prepared for immediate action, and I hold that all divisions, squadrons, or fleets should be so prepared at all times; the component parts—"parent," "children," adjunct or auxiliary—for opposition to the hostile force, from whatever quarter it may come, being complete and prepared as a whole, so as to be ready for immediate muster at a given rendezvous.

That the means by which such a desirable end may be obtained are now in full swing is a fact upon which the country, and especially those who have the fearful responsibility of directing the progress of naval administration, can not receive too much congratulation.

What I wish to combat in the early stage is the idea that two, four, six, eight, or any number of ironclads form a fighting fleet, which I may safely state is generally accepted by the outside public; and I wish to prove that second only in importance to the parent ship are the children which she will have to man, fit out, command, feed, and generally protect and look after, with the assistance of the attendant coal, store, depot, and hospital ships.

I will now endeavor to lay before you what I believe to be absolutely necessary in the composition of the fleet of the future.

First, then, as to its numerical strength in units; I maintain that the time has gone by during which it was of paramount importance to mass a very large number of ships together, and therefore I propose to give to the term "fleet" a definite numerical value and strength, which should certainly not exceed twelve units, with their auxiliaries, and I can not conceive any concatenation of circumstances which would render it advisable to have a larger number acting as one body in an action on the open sea.

Taking the available vessels into consideration, and looking to facts as they stand, I am convinced that the best numerical organization for Great Britain at the present time is the divisions of three, forming squadrons of six, joining two of these squadrons, with their adjuncts and auxiliaries, if it became necessary to throw an overwhelming force on a given spot.

I would strictly adhere to the division of three, under a commodore or rear-admiral, as the first grade of superior responsibility; so that you could have three, six, nine, or twelve, each with its own component parts, as shown in the diagrams.

Every station should be capable of forming a division, squadron, or larger force in its own ground, and they should be so formed—adjuncts included (or such as it is not convenient to commission, accounted for, and proved to be ready if wanted)—at least once in every twelve months.

The type of fleet ship might differ on the various stations, but the principle would remain the same.

In the Channel, Mediterranean, and commissioned reserve forces I would have none but mastless turret or battery rams of the highest known speed and handiness and the most piercing gun power.

Thus we should have within reach of each other, and at no great distance from home, nine divisions, organized in two, three, and four divisions respectively, either to act separately and independently, or to co-operate, fully equipped and exercised, absolutely prepared for an immediate outbreak of war.

THE COMPOSITION OF THE FUTURE FLEET UNIT.

Having, then, proposed the number of units that should form a division, squadron, and fleet, I would now venture to lay down the least I consider these units should consist of.

First. As a basis, a first-class turret or battery ram, with only sufficient masts for the purposes of semaphoring and elevated machine-gun fire, or as near an approximation to it as can be obtained. She should be fitted with the electric light throughout, mast-head semaphores, complete net or other defense, etc., with one ram, guns, and torpedoes according to her carrying power, two second-class torpedo-boats of the latest pattern hoisted inboard, and two or more subaqueous boats, when perfected.

Second. At least two first-class sea-going torpedo-boats, capable of keeping the sea in all weathers, commanded by two of her lieutenants and manned by crews belonging to her complement.

Third. A fast turbine gunboat ram, very handy, to accompany her, as a rule in tow, fitted with search light and mine-removing apparatus, commanded and manned as before.

Fourth. A very fast at least 200-ton turn-about torpedo-boat catcher, destroyer, and look-out vessel, fitted with the latest improvements in torpedo discharge and machine-gun fire, commanded and manned as before.

Each of these adjuncts or children should be part and parcel of herself, considered as part of her armament and building expense, being laid up or not during her commissions according to the convenience or exigencies of the service. Their officers and crews being on the parent's books, would live, work, and train in her when not out for exercise, and as they would draw all their stores, provisions, etc., through the parent, only one set of non-combatants would be wanted for a complete fleet unit, the base supplying the wants of the component parts in every detail. When with the division, and especially after the declaration of war, they would be inseparable, the unit captain being responsible for everything connected with them to the divisional commodore.

Every three units or parent ships should have definitely belonging to them and told off for their use the following auxiliaries :

First. Two well-found and specially fitted colliers, capable of carrying 3,000 tons of coal each, one of which would be on duty with the division while the other was at the coaling depot filling up. These colliers will not be able to be snatched up haphazard on the spur of the moment, but after their special fittings, shoots, hatches, and winches have passed a rigid inspection, they should be told off, lettered, or numbered, as before stated, and their captains given some insight into the manner in which a large force is moved on the open sea. Speaking generally, there would never be less than 1,000 tons present with the force for each fleet unit, or its equivalent in liquid fuel.

Second. A very large merchant steamer, with great speed and cargo capacity, to act as "general store" and "spare ammunition" ship, carrying boom gear, spare shot, shell, etc.

Third. A torpedo-depot and telegraph-construction ship, with half the fitters from the squadron torpedo depot, carrying automatic torpedoes and electric cables, etc.; also a powerful tug, fitted with extreme pumping power, hydrants, and armed with machine-guns, and a divisional hospital ship. This force would thus form a complete division under a commodore, or a rear-admiral, if you could spare one.

The composition of a squadron under a senior rear or vice admiral would allow of its being a little more complete.

First. Four colliers of 3,000 tons capacity, two always with the squadron, having the same qualifications as before mentioned.

Second. A fast torpedo-depot ship of large coal and cargo capacity, and second-class boat-carrying power, with various mines and "spare automatic torpedoes."

Third. A fast "general store, timber, and caisson ship," carrying all gear ready fitted, connected with the laying of booms, and six mining launches.

Fourth. A fast spare-ammunition ship, having on board a proportion of projectiles of the caliber of each unit. She should have large capacity, as, owing to greatly increased weight and decreased reserve of buoyancy, the limit to the ammunition carrying power of the fleet ship will be severely felt in the future; and I look upon the spare-ammunition ship as next only in importance to the collier. Take, for instance, the latest launched fleet ship *Victoria*, with a combined metal and powder discharge of 2,700 pounds per heavy gun; she would require ammunition handy after bombardment or prolonged fleet action. The spare-ammunition ship should carry six lighters.

Fifth. A large "liner" or P. and O., fitted as a hospital ship, carrying the red cross by day and in the presence of the enemy the electric cross by night, whose special duty would be to take on board all badly

wounded and fever cases, and also to pick up the crews of any ships that may happen to be rammed, blown up, or set fire to, etc. She should have numerous steam hospital boats at her davits and a divisional tender.

Sixth. A telegraph-construction and electric-cable ship for tapping, laying, and picking up cables, etc. She should also carry in her tanks cables of all sizes required for submarine mining.

And, lastly, two powerful tugs, fitted as before. It will thus be seen that for every parent or base unit there will be at least two first-class torpedo-boats, two second-class torpedo-boats, two subaqueous boats (when perfected), one torpedo-boat catcher, or lookout, one turbine gunboat ram, and one large merchant auxiliary.

A fleet would consist of two complete squadrons, and would thus have a force of 12 fleet ships, 24 first and 24 second class torpedo-boats, besides depot boats, 12 catchers, 12 gunboat rams, 14 large merchant auxiliaries, and 4 powerful tugs (besides the dispatch vessels present and running and provision ships working to and from the station depot), capable of changing its scene of operation at a high speed.

In addition to the adjuncts for defense, an attacking torpedo flotilla will be required, to work independently as a separate command. They would travel in charge of and defend the auxiliaries, one, two, or three to each, according to the numerical strength of the flotilla.

Any one who wishes to command a larger force in or out of action must have a good digestion. But should it be necessary to do so, this composition can go any length, and you can mass two or more fleets complete. A captive balloon in the flagship of the commander-in-chief might, on a clear day, enable your signal staff to count them. In my opinion the tendency in the immediate future will be to increase the adjuncts and decrease the number of parents.

ORGANIZATION, COMMAND, AND RESPONSIBILITY.

Fleet organization, I take it, simply means the distribution of your force in the most compact form, and marking the grades of command and responsibility at distinct points.

For instance, in the proposed fleet the lieutenants or warrant officers in command of adjuncts would be responsible to their captain, he in his turn being responsible for them, and all connected with his unit, to the divisional commodore, who in turn would be responsible to the squadron vice-admiral for everything connected with his division, who would again be responsible to the commander-in-chief for his squadron, the commander-in-chief being responsible to the admiralty and the country, directing and inspecting but not actively interfering with the work allotted to the subheads.

I have marked the first grade of ulterior responsibility at three units by the presence and command of a superior officer. In the naval force

of the future I would never have a captain in command of a division without giving him, if only temporarily, the rank of commodore.

To meet the demand you would probably have to create the permanent rank of commodore, to take the place of the present first fifty captains, for which any post-captain who had served a specified time in command of a ship of war at sea would be eligible to be selected for distinguished service, such as the destruction of any part of the enemy's force, etc.; and again, commodores, after a specified time in command of a division, might be selected for the rear-admiral's list on the same grounds. In the event of war some such plan as this will be wanted, or the rear-admiral's list largely augmented; probably the latter. Most likely other and better plans will occur to many present. I would only lay the rule of three down rigidly as to the composition of a division of units with their adjuncts and auxiliaries, but most certainly leave it in the hands of the commander-in-chief as to how the force should be distributed for action.

I wish to be very explicit about this point, and to place a wide gulf between the composition of the division, squadron, or fleet, and its organization for actual fight.

The first should be definitely laid down and prepared long beforehand—is probably preparing now—but to the admiral in command must be left the manipulation of the force for which he is responsible to the country. He may have a fancy for pairs, groups, indented lines of units; may have one form one day, and another form another day; in fact, he must be free!

We have yet to learn the most suitable and successful formation for attack and defense, but what we do know, and may predict with some certainty, is that the division, squadron, or fleet which is exercised and perfect in all known systems, and can rapidly change from one formation to another, has the best chance of winning an action.

Therefore I wish it to be clearly understood that I do not presume to advocate any system of group, pair, or other organization, but I do advocate a thorough knowledge of them all. Of course, it must also be left to the commander-in-chief as to what force he shall detach for minor operations; he may find it convenient to send a parent without her children, or with her first-class boats only, or with extra boats in any number; but in all cases the division or squadron to which the parent belongs should supply or keep the difference. The departmental organization places the force in the admiral's hands; after that they cannot be tied in any way. I am convinced that the division of three under a superior officer, call it or him what you will, is the best basis of organization for your main and auxiliary force, ready for immediate rendezvous.

Harbor routine (old).

Hour.	Summer.
a. m.	
4. 40	Call boatswain's mates, corporals, and mates of decks.
4. 45	Hands.
4. 50	Hands fall in, scrub upper deck. Duty boats' crews clean out.
5. 45	Hammock stowers, royal yardmen, and boys, lash up and stow, royal yardmen clean conductors, spread awnings.
6. 00	Lash up and stow.
6. 10	Steerage hammock men, watch below fall in, sound reveille.
6. 15	Cooks, up guard and steerage hammocks, bathe.
6. 30	Breakfast.
7. 00	Forenoon watch to clean in blue working dress, duty men and boats' crews in rig of the day. Watch below clean main deck and flats.
7. 15	Watch and duty boats' crews fall in, clean bright work; if top-gallant masts are down overhaul top-gallant rigging.
7. 50	Upper yardmen fall in, up all wet deck clothes.
8. 00	Evolution, then quarters, clean guns.
8. 35	Mondays and Wednesdays clean pump gear.
8. 50	Return rags.
8. 55	Disperse, hands to clean.
9. 10	Roll, sweepers.
9. 20	Quarters, prayers.
9. 45	Watch drill.
10. 00	Drills as ordered.
11. 00	Cooks, watch below, up spirits.
11. 30	Clear up decks.
12. 00	Dinner.
p. m.	
1. 25	Roll, sweepers.
1. 30	Watch fall in.
3. 00	Watch drill.
3. 50	Upper yardmen fall in.
4. 00	Evolution, quarters.
4. 15	Cooks, shift into night clothing.
4. 30	Supper.
5. 00	Both watches fall in, furl awnings, coil up ropes.
5. 30	Bathe, up boats not required.
7. 10	Steerage hammock men fall in.
7. 15	Stand by guard and steerage hammocks.
7. 30	Stand by hammocks.
8. 30	Clear up main deck.
9. 00	Out pipes, rounds.
9. 30	Pipe down.

Hour.	Winter.
a. m.	
5. 10	Call boatswain's mates, corporals, and mates of deck.
5. 15	Lash up and stow.
5. 30	Cooks.
5. 45	Breakfast.
6. 15	Hands to clean in blue working rig.
6. 25	Bath watches fall in, clean upper deck, upper yardmen clean lightning conductors, duty boat's crew clean out, up guard and steerage hammocks.
7. 00	Watch below clean main deck and flats, watch dry upper deck, coil down ropes.
7. 15	Overhaul top-gallant rigging if top-gallant masts are down.
7. 50	Upper yardmen fall in.
8. 00	Evolution, then quarters, clean guns.
8. 35	Clean arms Tuesdays and Thursdays, clean pump gear Mondays and Wednesdays.
8. 50	Return arms or rags.
8. 55	Hands to clean.
9. 10	Roll, sweepers.
9. 15	Quarters.
9. 45	Watch drill.
10. 00	Watch fall in, drills as ordered.
11. 00	Cook's watch below, up spirits.
11. 30	Clear up decks.
12. 00	Dinner.
p. m.	
1. 15	Roll, sweepers.
1. 20	Watch fall in.
3. 00	Watch drill.
3. 50	Upper yardmen fall in.
4. 00	Evolution, quarters, coil up ropes.
4. 30	Cooks.
4. 45	Supper.
	TUESDAY AND THURSDAY.
	Routine for small arms.
a. m.	
8. 40	Return rags.
8. 45	Hands to clean.
9. 00	Clean arms.
9. 10	Roll, sweepers.
9. 15	G. put belts or return arms.
9. 20	Quarters.
	FRIDAY.
	A quarter of an hour is to be given for cleaning guns, then pump gear. Clean guns after quarters.

SUNDAYS.

SUMMER AND WINTER (PAST, PRESENT, AND FUTURE).

a. m.	
5. 30	Lash up and stow.
5. 45	Cooks.
6. 00	Breakfast.
6. 25	Steerage hammock men fall in. Reveille.
6. 30	Up guard and steerage hammocks, hands to clean in blue working rig, duty men in rig of the day.
6. 45	Watch below clean main deck, watch fall in, clean upper deck as ordered, then wood and bright work, duty boats' crews lower and clean out.
7. 30	Duty boats' crews to clean.
7. 50	Quarters, clean guns.
a. m.	
8. 30	Disperse hands to clean.
8. 50	Roll, watch fall in, clear up decks for divisions.
9. 30	Divisions, divine service.
p. m.	
3. 50	Roll, sweepers.
4. 00	Quarters.
4. 15	Cook's hands shift into night clothing.
4. 30	Supper.
5. 00	Coil up ropes.
	If awnings are to be spread, lash up at 5.15, spread awning at 5.30, furl at 5 p. m.

Sea routine (old).

Hour.	Summer.
a. m.	
3.30	Coil up ropes.
4.00	Scrub deck.
5.45	Reset sails, etc.
6.00	Spread awnings, hammock stowers, royal yardmen, and boys lash up.
6.15	Lash up and stow; royal yardmen clean lightning conductors.
6.25	Steerage hammock men fall in.
6.30	Reveille, cooks, up guard and steerage hammocks.
6.45	Breakfast.
7.15	Watch below clean lower deck; watch clean in blue working dress, duty men in rig of the day.
7.30	Watch fall in, stations, clean bright work.
8.00	Quarters, clean guns.
8.30	Clean pump gear on Mondays and Wednesdays.
8.40	Return rags.
8.45	Disperse, hands to clean.
8.55	Roll, sweepers.
9.00	Quarters, prayers.
9.30	Watch drill.
9.45	Drills as ordered.
11.30	Clean up decks.
12.00	Dinner.
p. m.	
1.25	Roll, sweepers.
1.30	Watch, fall-in, drills as ordered.
3.00	Watch drill.
3.45	Clear up decks, watch below shift into night clothing.
4.00	Cooks shift into night clothing.
4.15	Supper.
4.45	Roll, both watches furl awnings.
5.00	Quarters, evolution.
7.10	Steerage hammock men fall in.
7.15	Down guard and steerage hammocks.
7.30	Stand by hammocks.
8.30	Rounds.

Hour.	Winter.
a. m.	
3.30	Coil up ropes.
4.00	Scrub decks.
6.00	Hammock stowers, royal yardmen, and boys, lash up.
6.15	Lash up and stow.
6.25	Steerage hammock men fall in.
6.30	Reveille, cooks, up guard and steerage hammocks.
6.45	Breakfast.
7.15	Watch below clean lower deck; watch clean in blue working dress, duty men in rig of the day.
7.30	Watch fall in, reset sails, clean wood and bright work.
8.00	Quarters, clean guns.
8.25	Clean arms.
8.35	Return rags.
8.40	Disperse, hands to clean.
8.50	Roll, sweepers.
9.00	Quarters, prayers.
9.30	Watch drill.
9.45	Drills as ordered.
11.30	Clear up decks.
12.00	Dinner.
p. m.	
1.15	Roll, sweepers.
1.20	Watch fall in, drills as ordered.
3.00	Watch drill.
3.30	Shift into night clothing.
3.50	Roll, sweepers.
4.00	Quarters, evolution, cooks, supper.
7.10	Steerage hammock men fall in.
7.15	Down guard and steerage hammocks.
7.30	Stand by hammocks.
8.30	Rounds.

TUESDAY AND THURSDAY.

Routine for small arms.

Hour.	
a. m.	
8.25	Return rags.
8.30	Hands to clean.
8.45	Clean arms.
8 50	G. put belts on, or return arms.
8.55	Roll, sweepers.
9.00	Quarters

FRIDAY.

A quarter of an hour only to clean guns, then pump gear. Clean guns after.

Weekly routine (old).

Hour.	
	MONDAYS.
a. m.	
	Air bedding.
8. 00	Cross upper yards.
9. 00	Lash up or inspect bedding.
9. 45	General exercise aloft.
p. m.	
3. 00	Watch drill.
4. 00	Down royal yards, evening quarters, wash clothes, alternate weeks scrub hammocks.
	TUESDAY.
a. m.	
5. 30	Lash up and stow.
5. 45	Up, scrub hammocks.
6. 00	Spread awnings.
8. 00	Cross royal yards.
9. 45	Watch drill.
p. m.	
4. 00	Down top-gallant masts, evening quarters.
	WEDNESDAY.
a. m.	
7. 45	Overhaul top-gallant rigging.
8. 00	Cross royal yards, loose sails.
9. 45	Watch drill.
11. 15	Furl sails.
p. m.	
3. 00	Watch drill.
4. 00	Down top-gallant masts, evening quarters.
	THURSDAY.
p. m.	
7. 15	Overhaul top-gallant rigging.
8. 00	Cross royal yards.
9. 30	Landing party.
10. 15	Marines
11. 15	Furl sails.
p. m.	
4. 00	Down royal yards, evening quarters, wash clothes.
	FRIDAY.
a. m.	
7. 15	Cross royal yards.
8. 00	Prepare for action.
9. 45	General quarters.
11. 15	Cross royal yards, down upper yards.
p. m.	
	Scrub canvas gear, up yards, etc.
	SATURDAY.
a. m.	
3. 00	Up, clean hammocks, alternate weeks.
4. 00	Mend furl of sails, evening quarters.
	Note.—On Tuesdays in Winter:
6. 25	Up, scrub hammocks.

Proposed new weekly routine turret fleet (harbor).

Hour.	Monday.	Tuesday.	Wednesday.	Thursday.	Friday.	Saturday.
a. m. 4 or 5 to 7.50.	Clean ship, men, and boats.	Clean ship, men, and boats.	Clean ship, men, and boats.	Air bedding, clean ship, men, and boats.	Clean ship, men, and boats.	Clean ship throughout.
8.00	Fire a torpedo					
8.00	Clean guns and small arms, and pump gear.	Clean guns and small arms.	Clean guns and small arms and pump gear.	Clean guns and small arms.	Clean guns and small arms.	Do.
9.00	Morning quarters, inspection, prayers, and stand easy.		Morning quarters, inspection, prayers, stand easy.		Morning quarters, prayers, stand easy.	Prayers.
9.10		Morning quarters, inspect men and arms, prayers, stand easy.		Morning quarters, inspect bedding, lash up and stow, prayers, stand easy.		
9.40	Out net defense, furl and restow nets, classes of the watch.	Small arm companies by company leaders, marines heavy gun, then classes as on Monday p. m.	General quarters, with day boat attack, combined or separate, twice a month.	Landing party, complete, stokers, etc. Land alternate Thurdays with marines.	Prepare for action. Net defense, and first-class boat attack once a month. Collision mats. Clean guns and decks.	Clean ship and guns.
11.30	Clear up decks	Clear up decks	Clear up decks	Clear up decks	Clear up decks	
Noon	Dinner	Dinner	Dinner	Dinner	Dinner	Dinner.
p. m. 1.15	Fall in, mining, signal, rifle, cutlass, pistol, knotting, splicing, and cable joining. Heavy, machine, and field-gun classes. Compass, lead, etc.	Fall in, lay out an anchor or fire-engine, or prepare to tow or be towed, then classes as on Monday.	Fall in, classes as on Monday p. m. Boat tactics.	Make and mend clothes. Leave, etc. Gymnasium open.	Fall in, classes as on Monday p. m. Scrub canvas gear. Boat tactics.	Fall in, clean bright work.
3.30	Clear up decks	Clear up decks	Clear up decks	Clear up decks	Clear up decks	
4.00	Evening quarters	Evening quarters	Evening quarters	Evening quarters	Evening quarters	Evening quarters.
4.30	Supper, leave, gymnasium, and pulling boats' crews.	Supper, leave, gymnasium, pulling in boats	Supper, leave, gymnasium, pulling in boats.	Supper, gymnasium	Supper, gymnasium, pulling boats' crews.	
5.00	Wash clothes, alternate weeks scrub hammocks.			8.30 exercise a regular system of night patrols by boats, in connection with the		
9.00	Watch night signals	Watch-night signals	Watch night signals	Day men at signal exercise.		

EVERY TWO MONTHS, WEATHER AND CIRCUMSTANCES PERMITTING.

First week. Lay and raise a combined minefield, assisted by torpedo-depot ship.
Second week. Build a boom, assisted by general-store ship. Attack and defend it at night. Gunboats, torpedo and guard boats.
Third week. Night attack by boats on squadron or fleet. Electric light defense by gunboats. Lay caissons or pontoons and nets to protect auxiliaries.
Fourth week. Countermine a dummy minefield, clear a passage, and raise.

Proposed new harbor daily routine.

Hour.	Summer.
a. m.	
4.30	Call boatswain's mates, etc.
4 45	Hands.
4.50	Hands fall in, scrub upper deck. Duty boats' crews clean out.
5.45	Hammock stowers and boys lash up, spread awnings.
6.00	Lash up and stow.
6.10	Steerage hammock men fall in, sound reveille
6.15	Cooks, up guard and steerage hammocks, bathe.
7.00	Forenoon watch clean in blue working dress, duty men and boats' crews in rig of the day. Watch below, clean main deck and flats.
7.15	Watch and duty boats' crew fall in, clean bright work.
7.50	Up all wet deck clothes.
8.00	Colors, quarters clean guns and small arms, Tuesdays, Thursdays.
8.35	Mondays and Wednesdays clean pump gear.
8.55	Disperse hands to clean.
9.10	Roll, sweepers.
9.15	Quarters, prayers; stand easy.
9.45	General exercise and drills as ordered.
11.00	Cooks, watch below, up spirits.
11.30	Clear up decks.
12.00	Dinner.
p. m.	
1.20	Roll, sweepers.
1.25	Quarters then fall in.
1.30	Drills and classes as ordered.
4.00	Quarters.
4.15	Cooks, shift into night clothing.
4.30	Supper.
5.00	Furl awnings, bathe, up boats, voluntary gymnastics, and pulling boats' crews, leave.
7.10	Steerage hammock men fall in.
7.15	Stand by guard and steerage hammocks.
7.30	Stand by hammocks.
8.30	Clear up main deck.
9.00	Out pipes, rounds, signal exercise.
9.30	Pipe down.

Hour.	Winter.
a. m.	
5.10	Call boatswain's mates, etc.
5.15	Lash up and stow.
5.30	Cooks.
5.45	Breakfast.
6.15	Hands to clean in blue W. R.
6.25	Both watches fall in, clean upper deck, duty boats' crews clean out, up guard and steerage hammocks.
7.00	Watch below, clean main deck and flats, watch dry up, etc.
8.00	Colors, quarters clean guns.
8.35	Clean arms Tuesdays and Thursdays, pump gear Mondays and Wednesdays.
8.50	Return arms or rags.
8.55	Hands to clean.
9.10	Roll, sweepers.
9.15	Quarters, prayers; stand easy.
9.45	Fall in, general exercise or drills as ordered, classes, etc.
11.00	Cooks, watch below, up spirits.
11.30	Clear up decks.
12.00	Dinner.
p. m.	
1.15	Roll, sweepers.
1.20	Fall in, drills and classes.
4.00	Evening quarters.
4.30	Cooks' supper, leave, gymnasium, pulling boats' crews, up boats.
7.10	Steerage hammock men fall in, 7.15 guard and steerage hammocks, 7.30 stand by hammocks, 8.30 clear up decks, 9 out pipes, rounds, signal exercise.
	TUESDAYS AND THURSDAYS.
	Routine for small arms.
a. m.	
8.30	Return rags.
8.35	Hands to clean.
8.50	Clean arms.
9.05	Roll, sweepers, on belts.
9.10	Quarters inspect and return arms, prayers, etc.

PEACE ROUTINE AND EXERCISES.

The smartness, order, and also the comfort of every force, no matter of what it is composed, depends almost entirely on its system of routine and exercises, the arrangement of which should insure that the largest possible number are at all times receiving the utmost amount of instruction and benefit from exercises that will be of the greatest use to them when they have to assist in the numerous and different kinds of operations which the royal and mercantile navy will be called upon to perform in any war sufficiently serious to endanger the safety of this Empire, and at the same time bringing no heavy strain on any body of men or portion of time.

Having stated that yards and sails are sinful and impossible in a fleet ship, I propose to give the whole of the time and care that has till now been bestowed on them to the *Excellent* and *Cambridge*, *Vernon* and *Defiance*, and to the signal and tactical school which is at present

an unknown quantity, but which I venture to predict will yet have a place in our training system.

The necessary supply of men for such vessels as are still fitted with sail power must be trained in the brigs and training squadron, or in the sailing sloop especially attached for that purpose; no time can be allotted in the turret fleet routine for that training.

The nature of the required instruction having more of an educational character, points to the development of the training-class system, and assimilating the drills to the school courses.

It is quite clear that the schools cannot supply the force in commission with a full complement of trained seamen, gunners, and torpedo men; nor is it at all necessary that they should. But they can and do supply a sufficient number for instructional purposes.

So that in the same way that the old line-of-battle ships fitted out with probably only a fourth of their crew who had ever been to sea before, and had to make seamen of them all in the shortest possible time, the fleet ship of to-day will have to start with as many seaman gunner torpedo men and marine artillery miners as can be spared, and these will instruct every man on board during the commission. There is not the slightest reason why any amount of men may not be trained as S. G. T. in the fleet on the same lines that they are trained in the schools. Let the rating of acting S. G. T. be open to all, and lay down your routine and drills with a view to giving all hands the best chance of becoming so.

WEEKLY ROUTINE IN HARBOR.

In these divisions and squadrons the criterion of smartness and efficiency will be the time taken to lay a minefield, build a boom, out and in net defense, countermine a channel, instead of up and down masts and yards, shifting topsails, etc.

In the particular service force a torpedo was fired at 8 a. m. before cleaning guns; but with ships continually together, once a week would be ample for this exercise, and I propose Monday morning.

Then during the forenoon let "net defense" take the place of general exercise aloft, and in the afternoon, and whenever there is no general exercise, let there be a definite and well-understood system of training classes in heavy, field, and machine-gun drill, submarine mining, rifle drill, cutlass exercise, signals, knotting and splicing, electric cable joint making, compass, lead, wheel, and gymnastics. Every seaman, stoker, and marine on board should go through all these classes.

On Tuesdays the small arm companies should be exercised on board by their leaders, and on Thursday landing party complete. Where the nature of the port will admit they should be landed for exercise, field and machine guns included, alternately with the marines, at least once a month, and brigaded once a quarter.

On Wednesdays short general quarters, with boats away for boat attack every alternate Wednesday.

On Fridays prepare for action in every detail, having a first-class boat attack once a month.

Both officers and men should go through a systematic training in boat evolutions in their turn on Wednesday and Friday afternoons, or even more frequently in convenient harbors, concluding with ramming drill.

The usual practice in laying out anchors, landing fire-engines, preparing to tow, or be towed, could take place on Tuesday afternoons; and a complete and regular system of guard-boat patrol, as it will be required during war, should be organized and exercised on Thursday nights, after make and mend clothes day, and during the night signal exercise of the daymen and yeomen.

There should be a complete gymnasium on board every fleet ship, horizontal bar, clubs, dumb bells, etc., open to all after working hours.

Besides the weekly routine, where the weather and the nature of the service will permit, every two months should contain a record of combined work, approximating as nearly as possible to what we shall have to do in the event of war.

First week. Lay, test, and raise a complete minefield.

Second week. Build a boom. Attack and defend it at night, using gunboats, guard-boats, etc.

Third week. Night attack by all available torpedo-boats on the force at anchor, electric-light defense by gunboats. Auxiliaries, if present, defended by caissons or pontoons and nets.

Fourth week. Countermine a dummy minefield, clear a channel, and raise.

These exercises should be carried out at least six times during the year; and once a year half the station force should attack the other in harbor.

This routine would be the guide and basis for the exercises of the fleet, squadron, or division, subject to the invariable etceteras of coaling, provisioning, docking, general leave, etc.

At sea.

With the proposed number of attendant gunboats and catchers on the station, the parent ships would not necessarily be much at sea. The officers and signalmen could go out in turn in the gunboats under one of the admirals or commodores, accompanied or not by the first or second class boats, and learn all the signal-book detail, evolutions, etc., having been previously put through the preliminary by the flag captains in the steam pinnaces.

But when at sea, "general quarters," "preparing for action," company drill, landing party, and the class drills would be the same as for harbor.

The time of the captain and the executive officers not on special duty during the day would be taken up with tactical maneuvers, and also the crews of the first-class boats if in company. A glance at the diagram

will show that practice will be wanted for the catchers and boats, and for whatever auxiliaries may be out; though with well-trained and prepared officers a week or two should be ample.

It will be absolutely necessary to exercise the divisions or squadrons, if you have them, in passing through one another at close quarters, with their advance guard of catchers, center support, and rear guard-boats, and after a little practice they should fire blank while doing so; and again, night exercise with and without lights, and with a system of signals based upon the minimum display of light, and no fireworks.

No exercise which can accustom the parents, adjuncts, and auxiliaries to move in concert and carry out previously planned combined operations, can be too often gone through. It is the seamanship of the future; and if it be certain, as I believe—and every one seems to argue—that we shall be enveloped in smoke from beginning to end, then exercise in smoke!

Lieutenant Sturdee in his prize essay[1] speaks of the Russian fleet being divided into two portions, one of which attacks the other with all the vigor of real war, and suggests the same for our own force. I am entirely of the same opinion, and I firmly believe that it is one of the very few roads, and the most direct, towards the elucidation of those vital naval questions which are crowding on us with ever-increasing rapidity, and it would be a crowning effort in that tactical education for our officers and men, which for years I have done myself the honor of advocating, both in this theater and elsewhere, with all the fervor at my command.

At least once a year, and for a period of not less than a month, the whole station force should muster and go to sea for exercise. During this time the maneuvers can not be made too real, and even risks must be run in order to insure high tactical training and skill.

The certainty of the superior officers being killed in the early part of an action, and the probability of ships being sunk or disabled, leads to the establishment of a system of filling up casualties (as at gun drill) both in ships and officers.

To make it entirely chance work the names of the ships, admirals, commodores, and captains, and name or rating of all commissioned officers, should be painted on tallies, and placed in a bag on the poop of the flag-ship.

During combined maneuvers and general quarters, they should constantly be drawn, and ordered off duty by signal, the next in command taking the place of his superior, and, if he should be the senior executive left, becoming responsible for everything connected with the ship.

The commander-in-chief would take his turn with the rest, and, when drawn, the flag-ship would have to take a subordinate station, her place being filled by the second in command, an organized close-up taking

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[1] Journal, No. 134.

place amongst the remainder. If a divisional leader were drawn, the close-up would of course only affect his division, the second taking command and temporary rank.

Weather permitting, the force should constantly be exercised in filling up with coal at sea; and the colliers should all be fitted with shoots, to shoot the coal on to the decks of the parent vessels.

The second-class boats might be hoisted out, exercised in skirmishing and screw fouling, and hoisted in, once a week, on the most suitable day. In connection with this exercise, I may remark that the present system of derricks is hardly suitable; and I should like to see cranes which would lift the boats and place them in the water. The above would be a guide to the routine at sea, with the addition of the necessary target practice, dummy torpedo-boat, and prize firing, etc.

SYSTEM OF LOOKOUT.

There can not be two opinions as to the importance of a systematic and dependable lookout by torpedo boat catchers and boats both by day and night, and also their manipulation on a considerable change of course, reversing, etc.

We have not far to seek for the reason for a lookout, ahead, on both sides, and in rear. From the high speed of the attacking boats in comparison with the normal speed of a cruising or blockading force, it is in their power to rush in from any quarter, presumably the most unexpected quarter; therefore, in your system of lookout, you must be careful to cover the largest possible arc on all points of the compass. In the conquest of Great Britain in 1888, Captain G., who destroys the British fleet, observes that they are protected with cruisers to the south, east, and north to prevent a surprise; but to the westward are unprotected, and therefore attacks from that quarter—of course in a properly organized division, squadron, or fleet—the proposition is absurd.

Each parent should have its own catchers and boats on its own line of lookout, according to its station. Leaders ahead, center ships the sides, and rear ships the quarters and astern. On reversing temporarily, positions need not alter, and the rear would become leading lookout; but if permanent, an executive signal would cause the boats to resume their normal relative stations.

RAPID COMMISSIONING.

Another feature of the future of our naval strength in divisions, squadrons, and fleets will be the rapid commissioning of parents and adjuncts and the short time it will take to get a complete unit to sea. Let us suppose a first-class turret or battery ram in the first division of the reserve of the future. Her first-class boats, catcher, and gunboat will be in close proximity to her second-class boats inboard. Her commander or navigating lieutenant, chief engineer, warrant officers, and permanent artificers on board, together with her coal, stores, mess traps,

etc. The trained nucleus of her complement would come from the force in commission, and the main body will have been made capable of performing their duty and fighting the ship in harbor drill-ships, or in batteries on shore, and they would only have to pick up their sea legs, and accustom themselves to the ship, when called out and embarked.

There seems no reason why a laid-up unit, division, or squadron should not put to sea on an emergency, if all your preparations were cut and dried, in less than twelve hours after the telegram has been received to fit them out.

COMPLEMENT.

With an economical arrangement, considering the rapid growth of mechanism, it does not appear that the complement of a complete unit need greatly exceed that of the fleet ship of the present, the increase being in artificers and reliable coxswains. We have already such a large and daily increasing number of specialists amongst the officers and men that we are gradually creating a class, consisting of those who have no letter tacked on to their name, and who are becoming known as "general service officers and men." This class will prove most valuable, and, though not considered competent to instruct in special subjects, they should be smart and well up in all kinds of gunnery, capable of laying and working a mine-field, making a boom, management of first-class boats, etc.; but especially in handling large ships, singly, or in any number, communication by signal, general organization, and in fact they are the seamen, whose only business is the seamanship of the new school.

I have long thought that all marines should gradually become "marine artillery miners," and I believe there now exists a consensus of opinion in favor of so simple a change.

Complements would thus commence with a proportion of specialists, and the remainder, general service officers and men, all of whom would be trained as specialists during the commission.

For instance, a "parent fleet ship" would carry (roughly)—

Officers.

Captain (special or general service)	1
Commanders:	
Special	1
General service	1
Navigating	1
Lieutenants:	
Special	6
General service	4
Engineers:	
Special	6
General service	6
Medical department	4

Pay department	4
Marine artillery, special 2, general 1	3
Warrant officers:	
Special	6
General service	12
Total	55

Men.

Special P. O.'s and coxswains	30
Special A. B.'s	20
General service, boats, etc	180
Marine artillery	80
Marine artillery miners	20
Signal P. O.'s	10
Second and third class signalmen and boys	20
Mechanics and stokers	120
Domestics, cooks, etc	20
Total	500

The above would officer and man the first and second class torpedo-boats, torpedo-catcher, and gunboat, the special commander looking after the adjuncts and the special outside work, the general service commander the ship, and the navigating commander the safe conduct, stores, &c.

A division would thus require three units, at	554 = 1,662
A squadron would thus require six units, at	554 = 3,324
A fleet would thus require twelve units, at	554 = 6,648

And allowing 100, all told, for each auxiliary, would bring the total to—

A division	1,962
A squadron	3,924
A fleet	7,848

With the service of the flags, the proposed "fleet" may be said to require 8,000 officers and men.

In the above estimate of complement I am presupposing increased mechanical appliances and the principle that we shall put "as few eggs into one basket" as we can possibly do.

BOOM DEFENSE.

I have referred to the building of a boom as part of the fleet exercise, and I have prepared a diagram (see plate) in order to explain what I mean. By itself it is not intended to keep an iron-clad in check, but it undoubtedly would stop boats and give a gunboat considerable difficulty. I claim for it that it is easy to put together, and that all gear, hawsers, moorings, etc., connected with it can be carried in the general store ship. Being in sections, each unit of the force present would place its own share and assist to reeve the hawsers.

It was planned with the idea of defending the entrance to the grand harbo , Valetta; but since then, I am told, the experiments at Bantry

Bay have clearly proved that a naval force should carry with it a ready-made boom, in sections, capable of being quickly laid and removed, which would at least stop torpedo-boats, delay gunboats, and could be quickly repaired. It seems to me that this would meet those requirements, but of course it has not yet had a trial, and is fairly open to your criticism. It consists of caissons or pontons connected by large cellular built nun buoys, spreading six of the largest made flexible steel wire hawsers, interlaced with small short steel wire, and spread with torpedo wire nets specially carried by the storeship for that purpose, the moorings and central weight being supported by large buoys between 1 and 2 fathoms below water.

A light frame-work floats on its danger side to keep off boats; and wire hawsers, especially fitted with tails, to catch the screws of attacking gunboats, would be buoyed out in the direction from which the attacking force would have to approach.

Besides defending the entrance of a harbor, or round the auxiliaries inside, it might be laid to stop torpedo-boats coming out of a blockaded port.

CONCLUSION.

In conclusion, I beg to point out that no one can regret more than I do that we can not carry all we require on one keel; and to some it may be a matter of regret that our wants can not be carried in ships whose officers and men belong to the Royal Navy; but we have to deal with facts, and that we shall have a number of component parts, royal, reserve, or volunteer, working together under subheads, who again are acting under a supreme director and organizer, is a fact which is brought home to those who study the subject, especially those who have recent experience with a large naval force. And in addition to what has been suggested, what does this mean?

It means an increased necessity for a highly trained and efficient signal staff, capable of insuring constant communication by day and night, between the commander-in-chief, leaders of squadrons, divisions, parents, adjuncts, and auxiliaries.

It means, as Sir Donald Currie pointed out years ago in a most valuable paper on "Maritime Warfare, etc.,"—"preparation long before wanted."[1]

It means "that a combined systematic organization of our gigantic royal and mercantile naval resources is imperative." And from what we hear we may assume that it is making rapid progress.

And, above all, it means an enormous "ocean volunteer force," for which ships, officers, and men of all sea-going mail or trading companies should be eligible, with depot battalions consisting of boatmen, fishermen, and in fact our sea-going population of every class and denomination; rivaling the defenders of our hearths and homes in numbers and efficiency, and transforming a glaring weakness, fearful to

[1] See Journal, No. 89.

contemplate, into a pillar of strength fit to support the traditional renown of the British Empire, whose ever-growing power has lain in the daring with which her mariners, whether employed by royal or merchant owners, have crossed the pathless ocean.

A great deal has been said about the loss of nerve and the consequent deterioration of the seamen; but I agree with Captain Fitzgerald, that "we may still have risky exercises."

It is clear that in actual war there will be quite an exhilarating atmosphere of risk, requiring highly-tempered steel nerve.

"Gopčevic" states, as lessons from his battles during the "conquest of Great Britain of 1888"—

"That the one ramming runs great risk if other opponents are near at hand."

"Torpedoes are dangerous to friend as well as to foe;" and I think he is not far off the mark when he concludes, that "the victor in a naval action nowadays must suffer as heavy losses as the vanquished."

One thing is clear, that should we be called upon to meet the enemies of our gracious Queen, it can only be by definite organization and by perfecting the whole of our vast naval resources in such exercises as I have humbly endeavored to advocate, that we can make certain of finding "in the darkness, smoke, and confusion of future naval battles, midst deafening explosions, outrivaling the cannon's roar, and the crash of the charging masses, as they hurl themselves on one another in one mighty effort of destruction, struggling for the very existence of their homes and country," that our ships are possessed of that unity which is strength, and our officers and men that knowledge which is power.

To my mind, it is not so much the deterioration of the British seamen we have to think of. You may develop his intellect and educate him without fear; and if systematic instruction in gymnastics be carried out, he will lose little of his muscular power. No. Take the yards and sails. In the attainment of the only object for which we exist, they are useless; and in the "interior economy of a modern fleet in time of war, they must prove disastrous."

Leave only a boat-hook on which to hoist the union jack, and depend upon it when the time comes its spots of glory will rival those of past ages, or it will wrap itself as a shroud round the ships and crews who may yet go down with their colors flying.

The CHAIRMAN (Admiral Willis): Before the discussion commences, Captain Campbell has asked me to read a letter from Lord Charles Beresford, with his remarks upon the paper. It is like all he generally says, very much to the purpose and terse.

[Extracts from a letter to the lecturer from Lord Charles Beresford, M. P., unavoidably absent at Yarmouth with his royal highness the Prince of Wales.]

1. I congratulate you on your paper; the pith of it is excellent. I wish I could have come to say a few words in support of many of your ideas.

2. Your "composition" for fleets and squadrons is sound, good, and necessary.

3. You wish for "systematic organization"—so wise. In other words, you want to teach officers and men what they will have to do in time of war, before they are called upon to do it.

4. Practice "condition and organization" in working fleets and boats at high speeds. Get rid of the ridiculous hamper and useless lumber of masts and yards which invite an accident to your screw, and so risk losing an action you otherwise would have won to a certainty.

5. Constant drill under steam will allow our commanding officers to understand how to carry out a sudden change of formation which might win them the action.

6. We are getting on, but *oh! so* slowly.

Signed, etc.,

CHARLES BÉRESFORD.

Rear-Admiral Hon. E. FREMANTLE: I did not come here this afternoon with the intention of saying much, if indeed I said anything at all, but as there seems to be some reluctance to commence the discussion, I am very glad to say a few words. I have had the pleasure of reading the lecture before I came here, and have done so with very great interest. I am quite sure many of the points which Captain Campbell has made will approve themselves to all here present. We must all allow that the general idea of a fleet consisting solely of half a dozen iron-clads, or a dozen iron-clads, is to a great extent an exploded one; a point I made very strongly about a year ago in this theater. We have always found it necessary in former times to have considerable adjuncts to the fleet. We know that Nelson said when in search of the French fleet, before the battle of the Nile, that the word "frigates" would be found written on his heart, because he could not get his lookout ships. These lookout ships are far more necessary now than they were then. We know, too, in the Russian war how necessary it was to have fleets of colliers, and what trouble they gave from their being sailing vessels and not able to follow the fleet; but now it is still more necessary, as our fleets are to depend entirely upon steam power. Under these circumstances the colliers undoubtedly become more necessary. Then we have the question of ammunition. We know that at the time of the bombardment of Alexandria our ships were short of ammunition, and there would have been great difficulty in continuing the bombardment, that in fact we could not have had another day's fighting on the same scale, and the ammunition reserve was called up in a great hurry from Malta and Gibraltar. Consequently we must see the necessity of having ammunition-ships as well as colliers. Our ships cannot carry a very large number of rounds per gun, and there is a tendency to reduce the number still further. I need not refer to the points in illustration of this given by the lecturer. When a vessel discharges at each broadside a shot of a ton weight, we must see clearly that a further necessity has arrived for having ammunition-ships. I will go a little further and mention also, with regard to the question of booms and nets which are required, that if we are to do away with masts and yards, which came in comparatively handy to form a boom such as was made

at Berehaven, we shall have to trust to the ammunition-vessel for booms and nets and spare gear, which make the impediments of which we form the boom. We know also how useful the *Hecla* was in keeping the torpedo-boats in order during the operations in Egypt. We want, in fact, a very large factory to accompany our ships. The object of the lecturer is that these things should be distinctly recognized beforehand, so that we shall not suddenly, on the outburst of war, find out that these adjuncts to a modern fleet are necessary and have to provide them in hot haste. When we come to the question of torpedo-boats, and the adjuncts for war, it becomes absolutely necessary that we shall have them prepared beforehand. That takes me to the question of the fleet unit. I think, admitting the principle of the lecturer, that there must be some adjuncts, it will be admitted that the adjuncts for fighting purposes may vary. Some part is left by the lecturer somewhat to our imagination. We see the turbine ram is mentioned to accompany the parent ship. Now, no doubt, if Sir George Elliot were here, he would be extremely angry at anybody throwing any doubt upon the success of the turbine principle in warfare; still at all events it has not proved itself hitherto a factor on which we can rely, and therefore the lecturer has drawn to a certain extent on what he thinks may be possible for the future rather than what is possible in the present. I think I may fairly express some regret that he did not confine himself to what is existing. However, to go to the question of the unit, I think on the whole the unit is very well worked out. We want certainly some sort of storeship, some sort of torpedo catcher, and certainly first-class torpedo-boats, if possible, to accompany every parent ship. Then we come to the question whether it will be advisable to make them so much distinctly the children of the parents as they appear to be in his plan. He has got vessels which are practically what I should call tenders of the parent ship. I think he has put it exceedingly well, because, as I understand, there is one commander expressly told off to look after the tenders, and who will no doubt have the responsibility for them entirely, of course under the captain of the parent ship. I think that is extremely necessary if we are to have them as tenders in the way the lecturer suggests. I have had some experience with tenders. When I commanded a ship in the north I had five tenders. I do not know whether any of the three commanders who I had the honor of serving under me during two years and a half of my command are present. They were all extremely good men and have, I am glad to say, all become post-captains since, but I do not think they had quite that parental interest in and regard for the well-being of the tenders which I had myself, and it would have been a great assistance if I had had a commander who would have assisted in keeping them in order and the crews complete. I only mention that as some objection to the parent system of making all these vessels as tenders, although there is a great deal which has been urged by the lecturer on the other side. Now we come to the

question of drill, and the lecturer tells us it will be an extremely good thing to do away with drill aloft, because, he says, there is great pressure. There is a certain paragraph in which he gives a not very exaggerated view of what he had to carry out as commander of the *Alexandra*, when I knew her in Malta harbor. We had to carry out a great many drills and exercises aloft, while at the same time under the commander-in-chief's orders we had very properly a very large amount of torpedo drill and torpedo-boat work, and none of the new things gradually growing up were neglected. The lecturer speaks feelingly of the difficulty he has felt in combining all this work, and in that I entirely agree. At that period I commanded a turret ship, and I have often been asked whether we found any difficulty in employing the men. Certainly in the early stages of their commission we found we had always plenty for them to do; the boat drills, torpedo drills, landing drill, gunnery drill, net exercises, and so on, gave us plenty to do, and as I am quite certain, although that ship is in commission now, and it is a couple of years since I left her, that they have always found plenty to do. The fact is that torpedo drills and gunnery drills are more thoroughly attended to in a mastless ship, and on the whole they are more efficient. They were certainly more efficient in gunnery and torpedo drills in the *Dreadnought* than they are in the *Agincourt*, the ship in which I am now serving, and I say that without wishing to throw the slightest imputation upon the excellent gunnery and torpedo officers of the *Agincourt*. When a ship has masts and yards, all the senior officers especially, who have been brought up in that school, will go back to their first love and feel most interest in drill aloft; it is such a satisfaction to them to see the mast and yards sent up in 1 minute 30 seconds or so. It looks so pretty to see the yards swing across as the ensign is hoisted at 8 o'clock, and the band plays "God save the Queen." Well, I regret to say that all that is pomp and show. I do not wish to speak of it disrespectfully, but I am afraid we must throw it all overboard as useless lumber. I should like to ask the lecturer what he refers to with regard to the second-class boats being exercised in fouling the screw. I entirely agree in what he says about second-class boats being hoisted out, that some easier method ought to be found than exists at present. I cannot understand why the engineering ingenuity, of which we have so much in this country, cannot favor us with something superior to the system we have now, by which a boat dangles from the derrick and swings about at the imminent risk of getting smashed. The only other point to which I specially wish to refer is that about signals. The lecturer, who has given great attention to this subject himself, being an accomplished flag lieutenant, tells us that he has had pertinently brought before him the difficulty that there is in getting sufficiently good assistance in the signaling department, and also that the school of tactics scarcely can be said to exist. In that I entirely agree. I may mention that there are some new signal books

about to come out, which we had the pleasure of trying in the Channel squadron. These new signal books are on a different system to a great extent to the old, that is, the endeavor has been made to use the semaphore more and fewer flags. That means a more complicated system in the receiving of signals, and we want a more experienced staff than we ever had before. The staff ought to be very much better than they are, and the signaling officers also very much more trained, otherwise we shall have great mistakes, and all our endeavors to make the commander-in-chief's orders and wishes easily made known to the fleet will be thown away, because the fleet will not be able to understand them. Under those circumstances it is very much to the point that the lecturer has told us that we must have a better tactical school and that the signal department must be improved and augmented. I thank the lecturer very much for the lecture, but I may say in conclusion that I think two ships would make a better division than three.

Lieutenant JACKSON: As one who has lately served with Commander Campbell in a masted iron-clad, I can fully testify that he has practiced in actual work that which he has preached this afternoon, and I can also uphold his very graphic description of the number of different evolutions often required to be done at the same time, and the difficulty the commanding officer has to overcome in keeping both sails and the more modern requirements of a ship all in a high state of efficiency. One other point as regards the retention of sails in a modern ship is the question of stowage and weight. In masted ships, when the stowage of sails, &c., is regarded as of primary importance, the stowage of the fighting material is often cramped, and the transporting arrangements rather deficient. These defects are entirely overcome in the mastless iron-clads, when sail power has not to be considered. There is plenty of opportunity for smartness left in rigging booms and nets, but working both nets and sails together seems to me to be sure to lead to the neglect of one or the other, and that, perhaps, the most important of the two evolutions. As regards the different points raised in this interesting lecture, I would remark that our present experiences prove the necessity of a mother ship for first-class torpedo-boats, to act as a base to the flotilla, the small quantity of stores and the minor repairs so often required necessitating a frequent return to the depot. Captain Campbell says the boat should be a perfect sea-going boat, but I am afraid when we go into that he will find that his sea-going torpedo-boat will be nearly as large as his torpedo-boat catcher. I think the plan of the mother ship will be found more efficient for cruising than attaching one or two boats to each ship, whose movements might be considerably hampered thereby, except in very fine weather. The iron-clad forming the base of the unit, also carries second-class boats, and she will have some torpedo-boats with her; and it is much to be hoped that the method of hoisting these boats out will be improved. The use of these second-class boats is very limited, as they are very dependent on the

weather, a slight swell preventing them being hoisted out and rendering them of not very great service when they are out. The attaching of a torpedo tender to each ship is very likely to form a most valuable addition to the fleet in war time, as their great speed and better seaworthy qualities than the ordinary torpedo-boat will make them almost safe against the latter if they only have sea room, their speed allowing them to destroy each boat in detail. They would also be able to do the attacking duties of torpedo-boats in weather in which the latter would have lost most of their value. I think the number of "Rattlesnakes" might with advantage be increased. The question of the complements of modern ships is also a serious one in our vessels where the crews are reduced to the very smallest number possible compatible with working the guns. It is to be hoped that the time usually devoted to sail drill in masted ships for the non-combatants will now be used for training them in the use of arms, where it is sadly needed. As regards subaqueous boats, although they are being developed, I do not think one has yet been designed that will meet our requirements, and their sphere of action will, I think, always be very limited. They are, however, by no means to be despised, but at present their room on board an iron-clad is of more value than their company. I would also place the turbine ram, with its necessary slow speed, in the division instead of the unit, and consider that she should be fitted as a miner and tender to the depot ship. As regards the seaman-gunner torpedo-men, the acting rating is now open to all A. B.'s, but they have to pass through the school ships to be confirmed, which, I think, is as it should be, as they get a much more advanced training than is possible at sea. With regard to the gymnasium, that is a very excellent institution on board. I can speak from practical experience. We have one now on board the *Vernon*, which is crowded every evening with young men very anxious to be taught, and many of whom it is simply impossible to tire out even by good gymnasts. It is a very popular form of amusement to them. With regard to the boom shown on the diagram, the only point I should like to raise is that there is no timber in it, which would render it possible to be destroyed by Whiteheads. I do not know where the nets go. If they are on the inner boom, they would stand a very good chance of sinking the boom with the Whitehead fired at the nets; they would explode the Whitehead underneath the pontoons and so sink the boom. That is the only objection I can see to it.

Captain the Hon. THOMAS BRAND: I shall not keep you many moments, but there is one point which has not been touched upon by any of the speakers, and which, I think, is worth mentioning, and that is rather with regard to economy. I have no doubt Captain Campbell is putting forward what he thinks we ought to have in the navy, but we must try to get on as far as possible with the means at our disposal, and, it is almost unnecessary to add, we are not likely to get more

money voted for the navy than we have at present. I should like Captain Campbell, if he gives us another lecture, to consider whether it is possible in an organization of this sort to have your parent ship manned sufficiently well for herself to be able to say that, on calling out the reserves, the reserves might be put in the parent ship, and certain portions of her crew sent to the adjuncts, so that you would actually be keeping your fleet at a rather less expense in time of peace than you would in time of war; for, according to this paper, you would have 32,000 men required for the fleet entirely outside anything in the way of protection of commerce. I was going to mention the turbine, but I need not do so, as Admiral Fremantle has referred to it. I think it would be very hard upon an admiral to say that the organization of the fleet on going into action is to be left entirely with him, because he is in a very curious position, when he has all these ships to take care of behind him. I think he would have to send most of them away altogether. The difficulty would be that for certain purposes and at certain times you want different ships. If you are going to bombard, you would want the ammunition, and might not want the colliers; but if you are going to cruise you want the colliers, but you would not want something else. It therefore seems to me very hard upon the admiral to say that he is entirely responsible for maneuvering the whole of those ships. With regard to masts and sails I am entirely in accordance with Captain Campbell, and I should think it would be a most excellent thing if a little excercise in coaling at sea were occasionally carried out.

Capt. W. H. Henderson, R. N.: On matters of principle, and as to the necessity for a higher form of organization than has hitherto existed, I quite agree with Captain Campbell, although on many points of detail I differ from him, but they are points open to discussion, and which can only be settled by experience and the shaping of means to ends. In no case can additional money be expended. What can be done must be effected with existing conditions. The old times have gone by, never to come back. It is necessary we should look at the new state of naval warfare straight in the face, and devote our energies only to essentials, to organization for war, and to the training of the rising generation of officers and men in the naval operations and seamanship of the day. All else involves loss of time, waste of strength and means, besides inviting disaster. I believe that naval developments are tending to assimilate operations at sea to operations on land, and that no naval force can be considered complete without its due proportion of the several elements representing the various types and classes of ships of the day, any more than a military force is complete without its due proportion of infantry, cavalry, artillery, and engineers. I believe, also, that as the efficiency of an army depends on its "mobility," and its "mobility" in great part depends on the organization of its transport, so in the future will the mobility and conse-

quent power of a naval force depend on the proper organization of its supplies. Whatever may be settled upon as the fleet unit, it should have its own definite proportion of transport. As an army must have bases, permanent and temporary, from which to draw its supplies, so in the future will the success of naval operations depend upon the manners and security of the bases, permanent and temporary, from which the fleet, squadron, division, or unit may be acting, and the ability to protect and keep open the necessary lines of communication. Each foreign station should have its proportion of force told off for it, so that on the outbreak of war, be it a unit, division, squadron, or squadrons, it would be complete, and easily concentrated either for offensive or defensive purposes, all that it would require being additional officers and men. The foreign dock-yards and fortified coaling depots, being the main bases of the naval stations, should be capable of repairing and supplying the force told off to them, and the permanent auxiliaries attached to the strength of each station should without doubt be kept at these bases. I think the gunboat attached to each unit should have independent powers of locomotion. It would not do to trust to its being towed. We do not require our ships to be as much scattered as they used to be for police purposes. They can cover much more ground in less time than formerly; besides, the police duties now mainly exist on the traditions of the suppression of piracy, of the slave trade, and the protection of British subjects in unstable and not fully organized communities, duties which fell to our lot to perform and which necessitated a scattering of force, but which are now gradually disappearing, and exist only here and there. The telegraph and good speed under steam are more efficient instruments in the hands of a commander-in-chief for meeting necessities of this sort as they arise. The squadrons on foreign stations may therefore be more concentrated and trained together for fighting purposes than has hitherto been the case, and if this were so would easily be able to look after and keep in order their smaller auxiliaries not kept permanently in commission. I protest against the idea that we require any special form of ship for police and cruising purposes in peace time. We want only fighting vessels, built without other thought or consideration, the smaller classes of which, with their superior speed and coal-carrying capacity, will do any cruising work that may be required, getting over the ground five times as fast and doing five times the work of any makeshift. In regard to the ammunition ships, I think it would be wiser not to put "all one's eggs into one basket" in this respect, and that it would be safer to fit the colliers to carry a portion of ammunition and stores, which would not much reduce their coal-carrying capacity. Captain Campbell's paper really goes to the root of our training system, and the question is coming on for solution whether both for officers and men it should not be adapted to the actual requirements of the day, instead of attempting to inculcate and make the foundation of all professional knowledge a passing form of seamanship which for

practical purposes is extinct and can never be even artificially revived, leading to waste of money, time, and dissipation of energies, which would be more profitably diverted into the direct channels of the seamanship of the day, a much more difficult and complicated science. There is not the slightest fear of the instincts and characteristics of the sailor being lost, be the form of seamanship what it may, and the knowledge and nerve now demanded in the every-day work and life of a ship is much greater than that which was required for exercises and evolutions aloft, and which have now no purpose in them. I do not think that a gymnasium is even necessary; a blue-jacket's duties are too diverse, he has so many different forms of hard manual labor to perform, and will still have lots to do with ropes and boats, ever to need the physical training of one. Rapid commissioning can only be efficiently carried out with a more thorough training of officers and men in the handling and management of the various complicated internal fittings and arrangements of the many classes of modern ships that exist at present; otherwise an immense number of defects occur from ignorance and carelessness. Temporary commissions are from the same causes fruitful sources of unnecessary defects, and involve large sums for repairs. Barracks are much wanted, and the men in the depots should be told off as skeleton crews to the ships ready for service. Cruisers should be attached to the units, and officers and men comprising a unit should all be trained in the management of the various descriptions of its components. It is our business and duty afloat to train officers and men in the seamanship and fighting conditions of the day. This can easily be done, and the unit kept in a high state of training and efficiency, but it is not, in a sea-going ship, easy to find the time. For the systematic instruction which goes on in the gunnery and torpedo schools it must necessarily be too desultory to be thorough. I think the boys should be trained in rifle, cutlass, revolver, and heavy gun drills before coming to sea. I would abolish the rating of trained men, and open the rating of S. G. T. to all, making the course in the gunnery ships shorter and sharper, and derating the pay of the trained men to the greater number of S. G. T.'s who would qualify. On return from foreign service every one should go through a qualifying or short requalifying gunnery course.

Rear-Admiral Colomb: I find myself in agreement with many details of the lecture, and yet my mind is so constituted that it would be impossible for me to have approached the subject as Captain Campbell has approached it. I can never look upon the organization of our fleets apart from geographical questions. I can not think for a moment how many ammunition ships, or storeships, or auxiliaries of any kind we require unless I have previously settled in what part of the world that fleet is going to act. I know quite well if we go to war with Russia we want one set of arrangements, if we go to war with China we want another set, and if we go to war with France we want another set. I can not bring my-

self to say that any unit such as is proposed can ever be established in that way. But when you take it in the broader way and say, as my friend behind me has said, that we must act upon bases as a rule, then I think it is true, and that those bases must be properly furnished with the necessary auxiliaries. I think proportionate auxiliaries for the ships that we have is becoming a matter of considerable importance. I quite agree that we should prepare in peace time regularly fitted colliers, regularly fitted torpedo vessels, regularly fitted ammunition ships. But to arrange them as a fleet, to say that a fleet is not complete unless she has so many of them, seems to me to be begging the question, because it will be complete or incomplete entirely according to the nature of the service on which that fleet is sent. I feel myself at sea in apportioning numbers or forming units in which such vessels are combined, because I can not say that I want so many iron-clads, so many torpedo-boats, unless I can just say exactly what I am going to do with them. I have not settled myself; I have not heard anybody yet who has settled it, and, in my opinion, till that is settled numbers can not be settled. Well, then, though I can not approach the subject in the same way as the lecturer has done, and though I can not settle it in my mind that we can by possibility start with a complete unit, and then aggregate it up to a squadron or a fleet, I know well that the feeling that such a necessity exists is very largely spread over the navy, and I take it that there must be some defect in my own organization that prevents me from accepting the position as it is put before us to-day. But, on the other hand, so much that the lecturer has said falls entirely into the way, I think, of these things, that I can not but express my concurrence with him on those points where I do agree. I am delighted to see he restores to us once more the idea that we are not bound entirely to destroy, but that there is some chance that we shall do what we used to do—capture our enemies and bring them into port. Then, when he speaks of the *Mammoth* and *Microbe*, which I think are two capital names, and will fix themselves in our ideas excellently, I agree with him there, but I do not think, whatever may be said by distinguished officers over the water, that the *Microbe* is to take the place of the *Mammoth* yet. How the *Microbe* and *Mammoth* are to be mixed depends again chiefly on the question of what you are going to do with the *Microbe*; how you are going to combine it with the *Mammoth*. How that is to be done I am not prepared to say. I am more inclined to think the *Microbe* has its business and that the *Mammoth* has her business, qualified by this, that it may be possibly true that the *Microbe* is to sweep the *Mammoth* off the sea. The hoisting out of torpedo-boats is one great question. Our ships are supplied with second-class torpedo-boats. I never can tell myself exactly how they are to be used. I feel certain that they can not be used in ordinary fleet action; that is to say, where the fleets meet in the open sea; sight each other 10 or 12 miles off at daylight, say, and approach one another. I can not think

of any fleet stopping to hoist out torpedo-boats, because it lays itself open to the attack of the other fleet, being found at slow speed. There may be some way of doing it. The idea of surrounding an iron-clad with a number of auxiliary vessels was put forward by Sir Nathaniel Barnaby, and then I was in the same difficulty. I wanted to know exactly what the *Microbes* are going to do, and I can not be satisfied that they are going to be there at all unless I am reasonably certain what their action is to be. I am delighted to hear the lecturer check the tendency to talk of the "fleet" in the singular number instead of the plural "fleets." That idea of the "fleet" is altogether and always one of the most mischievous ideas that has at present found its place in the English mind. I am certain it has cost us enormous sums of money in fortifications, and no doubt it will cost us a great deal more still. The idea is dangerous that there is only one fleet, and that one fleet is to be destroyed, or misled, or taken away, and that the mischief is to follow. We shall have "fleets," and if one fleet comes to grief we shall always hope there will be another fleet to take its place. I do not quite agree with the lecturer when he speaks of fleets and squadrons of the past as if they had something like the organization which is shown to us to-day. My reading of history teaches me that it was an entire toss-up what sort of auxiliaries a fleet of ships of the line had. I know of some cases where there was a small fleet and a very large number of frigates. I know of other cases, such as the expedition under Lord Howe, off the Straits of Gibraltar, with, I think, thirty-four sail of the line and only one frigate. In our far-back history, victualers and storeships were common, and in the wars with the Dutch, and later, fire-ships, as special weapons whose use was fully understood, accompanied the fleet. But there was no rule that I have ever been able to find about it. I strongly agree with the lecturer on the subject of exercises; I quite think that our men should be taught to fight and nothing else. Sail drill was a part of the fighting power in the old days, and was necessary for teaching as part of the fighting duty, but now that that is passed, the sooner we give it up and stick entirely to fighting powers the better. I was delighted with that other phrase that the lecturer has got hold of that "sails are sinful." I think that also is a phrase which will very likely carry its weight. There is another thing the lecturer has mentioned which I feel always strongly about, but as to which I am not quite sure that he has carried out the rule which he has laid down. He has told us the admiral's discretion must be free. The thing we have to do is to give the admiral every freedom; to take care not to tie his hands in any way whatever. But I should be afraid that if you propose that he shall not have a ship without the auxiliaries, that you do in some sort tie his hands to begin with. I am glad to see the lecturer always uses the term "fleet ship." It is a capital term, and I have often said so. You never forget when you hear the word "fleet-ship" used that that ship is to act in a fleet. I think the term "battle-ship" has been a

most atrocious and mischievous term. It means nothing; the consequence is the moment you begin to speak of a battle-ship you begin to think of a ship which is wanted to do you know not what. But when you speak of a "fleet-ship" you think of her as intended to act with other ships in concert. With regard to the smoke, we ought to study that question very carefully. I think the squadrons in the Channel and the Mediterranean ought to know thoroughly well what they can do and can not do with smoke. We find the most opposite opinions as to what is the right and wrong way of dealing with the question. Sir Leopold M'Clintock, I think it was, an eye witness of the fight between the Austrians and Danes off Heligoland, formed the opinion there that to get rid of the smoke you must fight to windward, and you must be to windward yourself to get the advantage. Commander Bainbridge Hoff, in "Modern Tactics," points out that to get clear of the smoke you ought to fight to leeward, because it is your own smoke which hurts you, not the enemy's. If you fight to leeward your smoke is blown from the mouth of your guns, your view is clear to windward; but if you, yourself, are to windward and the enemy to leeward, the bank of your own smoke floats gradually away and keeps an impenetrable veil between yourself and the enemy. Sham attacks are very important, and ought to be carried out to a great extent, and I am sure from personal knowledge the destruction in sham of superior officers is a very excellent exercise. I do not mean to say for the good of the service; of course it is for the good of the service if real. I have commonly, I may say almost regularly, made arrangements for having myself killed, and the fighting tower shot away, or the navigator killed, and the commander killed, and the fighting tower swept away. It used to be a regular formal exercise, first in simply killing the captain and saying, "I am dead; go on; there's the next man." Then everybody in the ship began to put their heads together and to see under these different casualties how best they could communicate with the next in command, where best he could command the ship from, and how there would be the least delay in filling up the place of the captain. Strong stress, I think, may be laid on the improved organization and great increase of the signal staff. It is ridiculous to me to see reports in the army of what they think, and of the money they have spent, and the training their people undergo in this matter of signals. It is not one-fiftieth of the importance that it is to the navy. Yet we in the navy, in all these years since our signal systems have been improved, have hardly taken any steps to increase or improve the signal staff, and now we are coming to that condition of things that all depends upon it. I do not see my way to an ocean volunteer force. I do see my way to a volunteer force which shall protect territorial waters, and I hope we shall get it, but as to an ocean volunteer force, I do not think that that is likely to be. I think the naval reserves, regularly paid by the state in times of peace, called on in times of war, may be very largely increased, but it

will not be as volunteers that they will serve, although they may and I hope will serve in the territorial waters round the coast. On the question of ramming, I see that the German writer referred to by the lecturer has done us the honor of quoting what was pointed out here years ago, that the ship ramming runs great risks if other opponents are near at hand. I forget what we called it, but we had a name for it; the ship next to the ship likely to be rammed was her guard, and it is a very difficult thing to attempt to ram any one ship if another ship is placed in such a position as to be her guard.

Admiral BOYS: I beg firstly to observe that the lecture to-day has been given by a comparatively young officer, and the discussion has been generally carried on by men about his standing. That I look upon as a very good sign of the interest taken in this institution, and proves its utility. The council are glad to find the junior officers in the services taking part in these discussions. With regard to the lecture itself I have very few words to say. My time afloat is over. It is, however, unquestionable that we ought to have some more recent description of organization than now exists, and something on the lines that have been so ably laid before us would probably meet our requirements. The only exception I should make to the proposed fleet organization is that I should cut out the turbine, because fleets now-a-days must proceed at high speed, and I do not believe that any turbine-propelled ship ever could attain the speed required. A great deal of stress has been laid upon the sail drill, etc., still carried on in masted ships. That point does not seem to bear very strongly upon the lecture, because, after all, we have very few iron-clads that are masted. Is it the fact that crossing yards, making sail, shifting topsail yards, and so on, interfere with the fighting drill of the service? I can hardly believe it myself; but, if it is so, I regret it very much. I still am of opinion that we cannot altogether take the masts and sails out of ships that are only fitted with single screws and single engines, and which have no auxiliary to depend upon, no reserve of mobility, except sail power. I think we certainly should leave some sails in such vessels to drag them along in case of accident. One speaker has intimated that every man in the fleet ought to be a seaman gunner or a torpedo man. That is by no means a novel idea, but it is simply an impossibility. The seamen gunners and torpedo-men are all supposed to be to a certain extent instructors, and there are many men who can not come to a sufficiently high standard of training to do the duties of these ratings, more especially to instruct other people. Whatever organization we may have to adopt, whatever training may be necessary, whatever we may have to meet in the future, all point to the necessity of continuous exercise and instruction in fleet maneuvers and tactics; and if, as is pointed out by the lecturer, the admiral and seniors of the fleet must be killed, then somebody else must replace them. The juniors can not gain the requi-

site experience in handling ships, etc., unless they are given the opportunity and actually put in the position to do so.

The CHAIRMAN: I will just make one or two remarks before I ask the lecturer to answer the points that have been raised. Admiral Colomb has mentioned many on which I should otherwise have touched. There is, however, this, that if, as the lecturer says, the parent ship is to contain 500 men and 54 officers, I think a great many of our turret ships at the present time would find considerable difficulty in accommodating those 500 men, and the 54 officers would certainly not find sufficient cabin room. But that is only a minor detail, because the principal adjunct, the largest ship of all, carrying coal, or any other ship could easily carry the superfluous men and officers which the parent ship could not accommodate; and I am not quite sure that the convenience of the smaller craft would not be better served by having their extra crews borne on board one of the large adjuncts. I quite agree with Admiral Colomb that every kind of service does not require the same kind of boat and adjuncts. One part of the paper to which I take exception is the necessity the lecturer finds in killing off the admiral! I only hope his successor will fill his place efficiently and have better luck. I will now ask Captain Campbell to reply.

Captain CAMPBELL: There really is very little to be answered. The question of the turbine was raised in the paper merely with the view of introducing everything as late as I possibly could, and as modern. I must confess I thoroughly believe in the turbine, and I put the turbine there for mining work, clearing passages, etc., etc. I have put her in tow of the parent ship on purpose. When she is really wanted for work it does not much matter about the speed; she will be able to move about quite fast enough when engaged in removing mines, when it is more important that she should be unsinkable than fast. Admiral Fremantle asked about fouling the screw. It really means this, firing off as much blank cartridge as you like, wrapping the ship up in smoke, and then letting your two torpedo-boats see if they can foul your screw by hawsers or other contrivance. For years I have been an advocate for greater practice and care taken to fit ourselves for some operation that will foul the screw of our enemy, because the whole ship depends upon a thing that you have stuck outside. If you can get hold of that thing and stop it the ship is done for and dead, and is absolutely no more use in an action, because the first ram coming along goes slap into her. If you can stop the screw (and why not?) it is worth while having practice of that description, and that you should have fouling practice of some sort is all that I wish to advocate. Captain Brand spoke of the expense. Now I was very careful to say I did not propose to enter into any question of building ships, but I would try to do the best I could with what we had got. This big organization does not mean that these are all turret ships; I only think we ought to have turret ships for home quarters; the others are what you can improvise on the sta-

tion. Then he spoke of the commander-in-chief having the fighting organization under his own control; that he must have. In the exhilarating influences under which he would have to fight his brain would begin to work at a pace which probably it had never worked at before, and things would occur to him at the last moment which it would be impossible for any one, including the enemy, to know anything about beforehand, so that he must be left to take his forces into action on any principle that may come into his head at that particular moment. He may have exercised it over and over again, he may have been struck with some particular form that he liked best, and he goes into action on that formation. That is the only thing I wanted to put forward—merely a scheme by which we may make certain that he will have the stuff to work upon, but the action details must be left to him. Lieutenant Jackson spoke of the independent mother ship as against the parent in the composition of the fleet unit. Even then you want organization, because before you have the mother ship you must have so many children. When you have twenty-four children then you want a mother ship, and my experience of these children is that twenty-four of them would give the mother ship a very considerable amount of trouble, and that is what has led me to believe that the fleet-unit system was absolutely necessary for mutual support and the defense of the parent; using the "mother-ship" principle for the attacking flotilla. Nearly all the propositions I have made to-day are debatable, and I am open to conviction on any point, and I have learned a great deal this afternoon. I thank you very much for the remarks you have made and the honor you have done me in attending.

The CHAIRMAN: It only remains for me to ask you to return thanks to our lecturer for his very interesting lecture. He is an officer who has considerable experience, and is well fitted to speak on the subject, which is one about which naval officers of the future and of the present must think a great deal. I hope that we have all learned something very considerable, and certainly we have a material which can be taken away and thought over, and I hope the results of that deliberation will be beneficial to the service.

COMPASS DISTURBANCES IN IRON SHIPS.

Lecture delivered at the U. S. Naval War College, in September, 1886, by Lieut. C. C. Cornwell, U. S. Navy, Superintendent of Compasses.

In bringing before you the subject of Compass Disturbances in iron ships, I wish to state that I do not claim any original investigation, and what I may say has been gathered from the many books already written on the subject, from a long and careful series of experiments, and from some recent experience on board our new cruisers.

All I propose to do now is to point out some important principles and facts, and to refer you to such books as the British Admiralty Manual, Evans's Manual, the writings of Dr. Scoresby, and the compilation of papers read before the Royal Society of London by Airy, Evans Smith, Rundell, and others, for a comprehensive and intelligent knowledge of the whole subject.

But little attention has heretofore been paid to this matter by the officers of the service, for the necessity has not arisen; but now that we hope to build up the Navy and obtain vessels of modern type, it is indispensable that the officers intrusted with their safe navigation should be familiar with the causes of compass disturbances and the methods of compass adjustment.

Before entering upon the subject of compass deviations, permit me to remind you of a few of the well-known principles of magnetism, as it will be necessary to keep these principles in view.

Referring to the earth's magnetism, the "line of force" is the direction which a freely suspended magnetic needle would take up if undisturbed by outside influences. The angle which the line of force makes with the horizon, known as the dip, changes with a change of latitude, being 90° at the magnetic poles, and zero at the magnetic equator.

A permanent magnet, composed of hard steel that has been artificially magnetized, retains its polarity in whatever position it may be held.

A rod of soft iron becomes a magnet by induction, while under the influence of a permanent magnet, and all traces of magnetism disappear as soon as the inducing influence is withdrawn. The earth, being a great natural magnet, exerts this inducing influence on all iron, thus rendering it magnetic, but still subject to its position with regard to

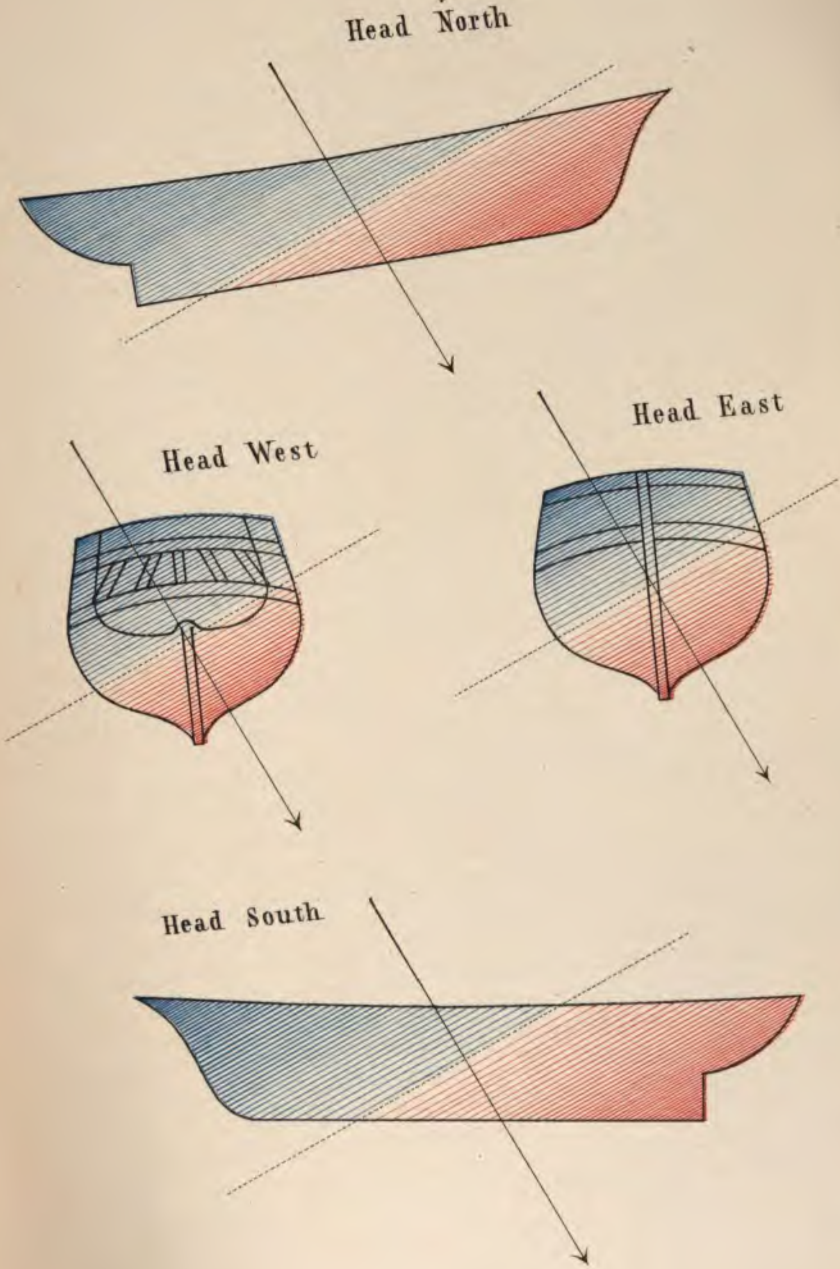
the earth's line of force for its power and the character of its poles. A rod of soft iron, held in the line of force, will become instantly magnetic, with a force proportional to the earth's total force at the place. Remembering that the pole of a magnet always induces, in the nearest end of a rod of soft iron, a polarity of an opposite name, it is evident that in the northern hemisphere the lower end of the rod will have north polarity, and its upper end south polarity. Reverse it end for end, and the lower end will still have north polarity, and the upper end south polarity; thus showing that the nagnetism of the rod was only of a transient character, depending upon its position. In order to prevent ambiguity, the north pole of a magnet, or the north-seeking pole of a magnetic needle, is distinguished by red, and the south pole by blue; and the earth being considered as a magnet, the northern hemisphere is pervaded with south or blue polarity, and the southern hemisphere by north or red polarity.

Retaining the soft iron rod in the magnetic meridian, and inclining it at an angle with the line of force, its magnetism decreases in proportion to the cosine of that angle, and disappears entirely when the angle is 90°. A horizontal rod in the magnetic meridian has a magnetism proportional to the earth's total force multiplied by the cosine of the dip, and in any other direction this magnetism decreases as the cosine of the angle which it makes with the meridian. In an east and west direction, a horizontal rod will have no induced magnetism.

The harder the iron the less susceptible it is of becoming magnetized by induction, and time is an element in the process of magnetization; but once magnetized, it retains its polarity with an equal tenacity, and will not instantly change or lose its polarity when its position is altered with reference to the line of force.

We are indebted to Dr. Scoresby for the discovery that the polarity developed in iron and soft steel by the inductive influence of the earth may be increased, controlled, inverted, or neutralized by mechanical violence, such as hammering, bending, twisting, etc.; and to him also are we indebted for many of the established facts concerning the magnetism of iron ships. It would be interesting to look carefully into the result of his investigations, but for our present purpose it is only necessary to state a few of the facts that he established.

Thus, the magnetism induced in a vertical rod of iron by the earth's action, is greatly increased by a blow with a hammer, and this magnetism becomes more permanent. If the rod be reversed, or turned at right angles to the line of force, it will not immediately reverse or lose its polarity, although either of these conditions will be effected by giving it another blow in the new position. Similar results can be produced by twisting, bending, or straining. In a sheet of iron the equatorial plane, or plane of no magnetism, will depend upon the position of the plate with reference to the line of force. A plate held upright in the magnetic meridian will develop south polarity in its upper part


Head North
Head West
Head East
Head South

and north polarity in the lower part, and the line of no magnetic attraction will pass through the center of the plate at right angles to the line of force. Dr. Scoresby has given the name *retentive* to that quality of magnetism elicited by mechanical violence, it being quite different from the qualities known as permanent or inductive. In his own words: "The inductive is transient, variable, or evanescent, with reference to a change of position; the permanent, such as that in hard steel magnets, is not affected, or only in a very slight degree, by position or ordinary mechanical action; but the other, whilst variable and changeable by mechanical action, may be *retained*, if the iron so magnetized be kept in a quiescent state for long periods of time, and even under great changes of position in relation to that of the polar force of the earth."

This peculiar kind of magnetism, elicited in an iron vessel during the process of construction, has been denominated *sub-permanent* by Sir George Airy, as a certain portion so acquired remains permanent; and this is the term now universally adopted. *Retained* magnetism is known as that magnetism which a ship may acquire from being in one direction for a long time, and it will be referred to farther on.

The inductive influence of the earth, aided during the process of construction by hammering and riveting, impresses upon the hull of an iron ship a distinct magnetic character, and the distribution of magnetism depends upon the locality and the direction of the keel while building; the polar axis conforming to the earth's line of force, and the equatorial plane at right angles to this line.

Thus (referring to the figures), in a ship built head *north* the upper part of the stern would be a strong south pole (if built in this latitude), and the lower part of the bow a strong north pole. In the ship built head *south* the upper part of the bow would be a strong south pole, and the lower part of the stern a strong north pole. In a ship built head east or west the whole upper part would have south polarity and the lower part north polarity; but in the former case the force in the upper part would be strongly developed on the starboard side, and in the latter on the port side. Keeping in view the fact that like poles of two magnets repel each other, and unlike poles attract, it will be evident that the north end of the compass needle, on board an iron ship, will be attracted to that part of the ship which was south in building.

The hull of the ship thus becomes a large magnet, although it has not the permanency of a steel magnet. It is subject to changes after launching, and probably loses a large amount of its magnetism as soon as the direction of the head is changed. It is thus important that an iron ship be turned around as soon as it is launched and fitted out with her head in a direction opposite to that of building. Ordinarily, the magnetism of the hull does not settle down to its permanent condition until the ship has been knocked about by the sea on various voyages. I shall have occasion to speak of this again when referring to the Atlanta and Boston.

Besides the sub-permanent magnetism we have the magnetism induced in the soft iron of the ship by the action of the earth; and the errors of the compass thus arise from two distinct sources. The deviation of the compass caused by the permanent magnetism has been called semicircular, because it attains a maximum amount in each semicircle during one revolution of the ship—easterly on one side and westerly on the other—the points of no deviation corresponding very nearly to the direction of the ship's head while building.

The effect of the soft iron on the compass needle depends upon its position being either vertical or horizontal. The magnetism induced in the soft iron by the vertical component of the earth's force produces a deviation of the compass analogous to that caused by the permanent magnetism, and hence it is also semicircular.

The magnetism induced in the soft iron by the horizontal component of the earth's force produces a deviation of the compass which changes its character in each quadrant as the ship swings round, and this has been called quadrantal deviation. In the NE. and SW. quadrants it is positive, that is, *easterly*, and in the SE. and NW. quadrants negative; being zero at the cardinal points and a maximum at the quadrantal points. On a change of magnetic latitude, the deviation of the compass due to permanent magnetism varies inversely as the horizontal force of the earth; that due to vertical soft iron varies as the tangent of the dip; and that due to horizontal soft iron remains constant.

The reasons for this may be stated as follows:

The directive force of the compass needle depends upon the horizontal force of the earth. At the magnetic poles, where the dip is 90°, the earth's horizontal force is zero and the needle has no directive force. The horizontal force increases as we go south, until we reach the magnetic equator, where the dip is zero and the horizontal force is a maximum. The disturbing force of the permanent magnetism of the ship remains constant, and its effect on the compass, causing a deviation of the needle, would therefore be inversely as the directive force, or the horizontal force of the earth.

The disturbing force of the magnetism induced in the soft iron of the ship by the vertical force of the earth varies as this vertical force, which is proportional to the sine of the dip; and its effect on the compass needle, therefore, will be directly as this vertical force, and inversely as the horizontal force (which is proportional to the cosine of the dip), and thus directly as the tangent of the dip.

In north magnetic latitude the upper end of vertical soft iron attracts the north end of the compass needle; on the magnetic equator it has no effect; and in the south magnetic latitude the upper end repels the north end of the needle.

The disturbing force of the magnetism induced in the soft iron of the ship by the horizontal force of the earth varies as this force; and as

the directive force of the needle varies in the same proportion, the effect on the compass will be the same in all latitudes.

In analyzing a table of deviations, separating the errors into their component parts and computing the values of the magnetic coefficients, use is made of the formula deduced by Mr. Archibald Smith. In this formula the expression for the deviation of the compass on any point is as follows:

$$\delta = A + B \sin \zeta' + C \cos \zeta' + D \sin 2\zeta' + E \cos 2\zeta'.$$

I do not consider it necessary to enter into the mathematical details of the derivation of this formula, but it would be well to state the meaning of the terms involved. The formula is only approximate, but it is sufficiently correct when the deviations are not excessive. A, D, and E are constants depending upon the amount and position of the soft iron in the ship; and B and C depend partly on the permanent magnetism and the soft iron, and partly on the dip and horizontal force of the earth. ζ' is the azimuth of the ship's head by compass, measured from north by way of east.

A, B, C, D, and E are known as the approximate coefficients; the exact coefficients being represented by the same letters in German type. The former are expressed in degrees and minutes, and the latter in arc. When the deviations are small, the latter are very nearly the natural sines of the former. When the deviations are large, the exact coefficients may be computed by means of a formula which will be given later on.

A is the constant coefficient, and its value is independent of the ship's head. It can have a real value only when horizontal soft iron is unsymmetrically placed with regard to the compass. It may have an apparent value, however, which depends upon errors of observation in obtaining a table of deviations, index error of the compass, and various other instrumental and personal errors which may occur in practice.

$B \sin \zeta' \times C \cos \zeta'$ are the two terms which represent the semicircular deviation. The semicircular deviation is, as has already been stated, due to the sub-permanent magnetism of the ship, combined with the effect of the magnetism induced in the soft iron of the ship by the vertical force of the earth. These two forces produce a combined effect called the semicircular force, and act in a definite direction in the ship with regard to the compass as a center.

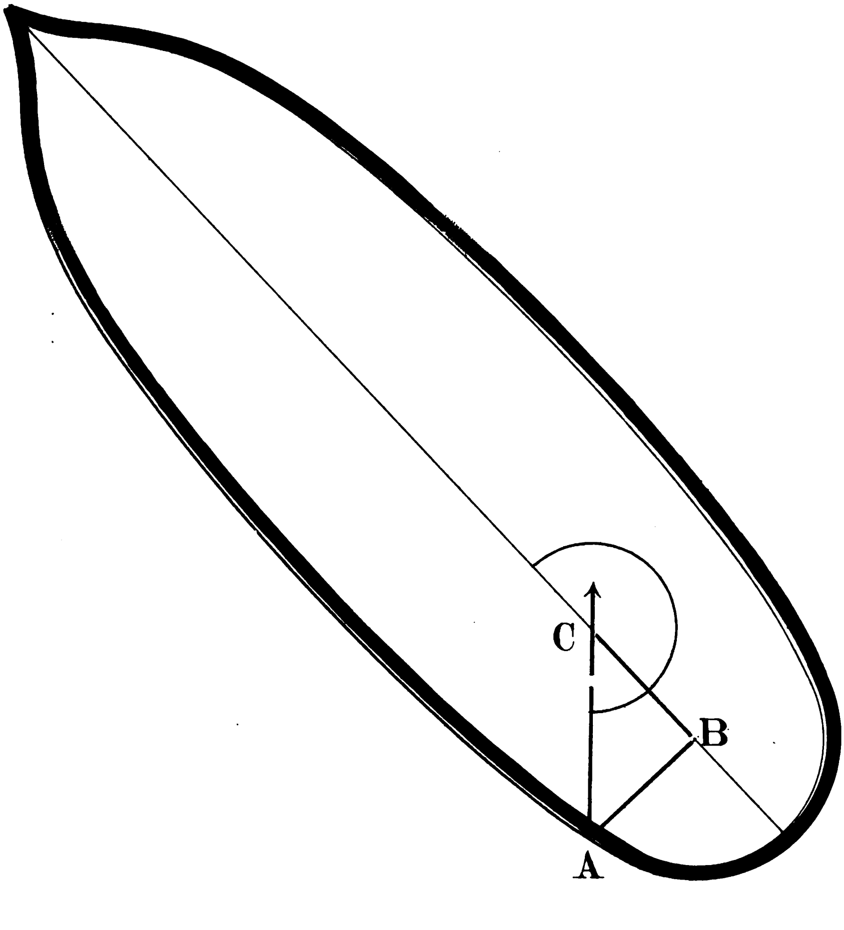
B is that part of the force which acts in the fore and aft line, and C the part which acts in an athwartship direction. B is positive if the force be forward of the compass, and negative if abaft it. C is positive if the force be to starboard, and negative if it be to port. The effect of these forces on the needle is referred to its north end: thus +B attracts it to the bow, and —B to the stern. +C attracts it to the starboard side, and —C to the port side. Suppose for a moment that the whole of the semicircular force be due to the permanent magnetism of

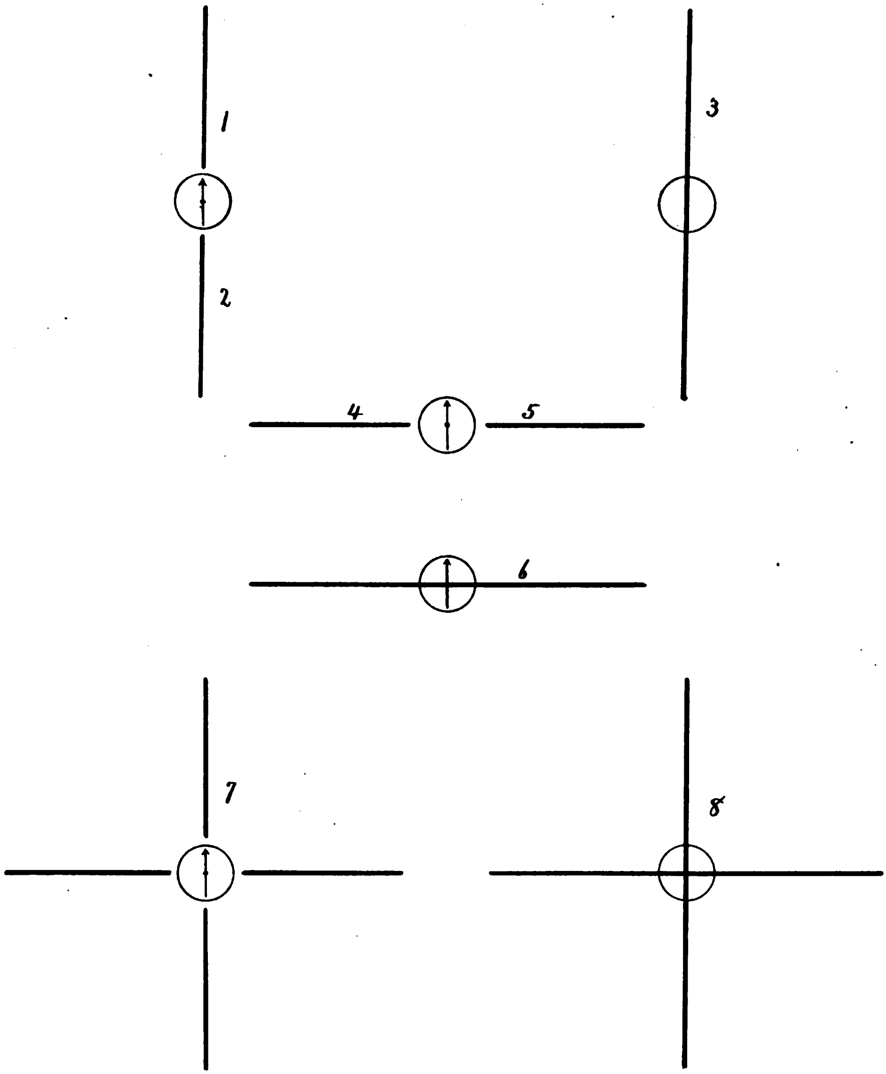
the hull, then the accompanying figure will illustrate the direction in which this force acts:

Assuming that the ship was built head NW., then the south pole of the hull would be on the port quarter, and the polar force would tend to draw the north end of the needle to that point. C being the center of the compass, the total force can be represented by CA, and the components would be CB$=-$B and BA$=-$C. This figure will also show that the points of no semicircular deviation correspond very nearly to the direction of the keel while building. When the ship's head is NW. the polar force acts in a line with the compass needle and cannot produce deviation. Its only effect, therefore, is to weaken the directive force of the needle on this course, as it acts in opposition to the earth's force. When the ship is heading SE. there will be no deviation produced, but the polar force, acting in conjunction with the earth's force, has the effect of increasing the directive force of the needle. The points of maximum deviation will be those at which the polar force acts at right angles to the disturbed compass needle. The total semi-circular force of the ship is the resultant of B and C, or $\sqrt{B^2+C^2}$, and the direction in which it acts forms an angle with the ship's head measured to the right and referred to the compass as a center, known as the starboard angle, of which the natural tangent is $\frac{C}{B}$. D sin $2z'+$E cos. $2z'$ are the two terms of the formula which represent the quadrantal deviation. E depends upon the magnetism induced by the horizontal force of the earth in soft iron which is unsymmetrically distributed with regard to the longitudinal plan of the ship; and generally it is so small that it can be neglected. In cases where an appreciable E exists it has its maximum value on the cardinal points and becomes zero on the quadrantal points. $+$E produces easterly deviation when the ship heads either north or south, and westerly deviation when it heads east or west. $-$E produces the opposite effect. D is the principal quadrantal coefficient, and it depends upon the induced magnetism in horizontal iron which is symmetrically distributed with regard to the longitudinal plan of the ship. D is always positive; that is to say, it produces easterly deviation as the ship swings from North to East and South to West; and westerly deviation from East to South and from West to North. It has a maximum value on the quadrantal points, and becomes zero on the cardinal points.

The effect of the soft horizontal iron on the compass is very clearly illustrated in the British Admiralty Manual, and I quote the following from that book:

It may be shown that when the soft iron of the ship is symmetrically distributed on each side of the fore-and-aft line, and when the ship is on an even keel, the whole of the action on the compass needle of the magnetism induced in the soft iron by the horizontal force of the earth may be represented by the action of two horizontal soft iron rods, the directions of which pass through the compass; one of such rods lying fore and aft, the other athwartships. Let 1 or 2 and 3 represent such a rod lying fore


C
B
A


1
2
3
4
5
6
7
8

and aft. The effect will be different, according as the rod lies in either position 1 or 2, entirely on one side of the compass, or in position 3, with the ends extending on each side of the compass.

When the rod 1, or the rod 2, is north or south of the compass, although it attracts the nearest end of the needle, it produces no deviation, because it acts in the direction in which the needle is pointing. When the rod 1, or the rod 2, is east or west of the compass, it ceases to be magnetic, and neither effects the direction nor the directive force of the needle. When the rod 1, or the rod 2, is NE. or SW. of the compass it produces an easterly deviation; when NW. or SE., a westerly deviation. Consequently, a soft iron rod in the position 1 or 2 increases the mean directive force, and causes a positive quadrantal deviation. So, a soft iron rod in the position 3 decreases the mean directive forces, and causes a negative quadrantal deviation.

A soft iron rod placed athwartships in position 4 or 5 increases the directive force and causes a negative quadrantal deviation. In position 6 it decreases the directive force, and causes a positive quadrantal deviation. Equal rods in position 7 would increase the directive force without producing deviation. Equal rods in position 8 would decrease the directive force without producing deviation; but in each of the cases 7 and 8 the soft iron would have an indirect effect on the deviation produced by other causes, by increasing or diminishing the directive force to be overcome in order to produce deviation; *i. e.*, the first arrangement would diminish the deviation produced by other causes; the second would increase it.

In the theory of compass deviations the rod 1 or 2 is known as + a; the rod 3 as − a; the rod 4 or 5 as + e, and the rod 6 as − e. The iron decks of a ship will produce − a and − e. The iron beams produce − e. An iron bulkhead will also produce − e, if it be under or nearly under the compass. Iron masts and funnels, the boilers and engines and turrets, will produce + a and − e if entirely forward or abaft the compass. The numerical values of the approximate coefficients, and thence the exact coefficients, are deduced by calculation from deviations observed on a sufficient number of equidistant compass points. The following table will illustrate the method of performing this operation. This table is adapted for the computation of the coefficients from observations of deviation on 32 points, or on the 16 or 8 principal points. Easterly deviations are marked +, and westerly deviations are marked −.

S_1, S_2, S_3, etc., in column 7, are the natural sines of the rhumbs 11¼°, 22½°, 33¾°, etc.; and in column 8, S_7, S_6, S_5, etc., are the natural sines of 90° − the rhumbs 11¼°, 22½°, etc., or the natural cosines of the rhumbs. In the latter part of the Admiralty Manual is a table of the products of every fifth minute of arc, from 5′ to 34° 55′, multiplied by the sines of the rhumbs; and by the help of this table the analysis of a table of deviations can be very quickly accomplished. The exact coefficients can be deduced from the approximate coefficients by the formulæ on the same sheet with the table of analysis. As an example of analysis, we will take the deviation table of the *Dolphin's* standard compass—

Analysis of deviations of the standard compass on board the U. S. S. Dolphin.

TABLE I.—COMPUTATION OF COEFFICIENTS B. AND C.

1.	2.	3.	4.	5.	6.	7.		8.	
						Computation of B.		Computation of C.	
Ship's head by standard compass.	Deviation.	Ship's head by standard compass.	Deviation.	Half sum of columns 2 and 4.	Half sum of cols. 2 and 4, changing sign in col. 4. Semi-circular deviation.	Multipliers.	Products of column 6 by multipliers.	Multipliers.	Products of column 6 by multipliers.
	° ′		° ′	° ′	° ′		° ′		° ′
North	− 8 45	**South**	+ 8 45	0 00	− 8 45	0	0 00	1	− 8 45
N by E	−10 50	S. by W	+16 00	+2 35	−13 25	S_1	− 2 37	S_7	−13 10
NNE	−12 30	SSW	+21 00	+4 15	−16 45	S_2	− 6 25	S_6	−15 29
NE. by N	−14 00	SW. by S	+25 15	+5 38	−19 38	S_3	−10 55	S_5	−16 19
NE	−15 45	**SW**	+27 30	+5 53	−21 38	S_4	−15 18	S_4	−15 18
NE. by E	−17 00	SW. by W	+27 30	+5 15	−22 15	S_5	−18 30	S_3	−12 22
ENE	−18 00	WSW	+26 00	+4 00	−22 00	S_6	−20 20	S_2	− 8 25
E. by N	−18 45	W. by S	+23 40	+2 28	−21 13	S_7	−20 49	S_1	− 4 09
East	−19 30	**West**	+20 30	+0 30	−20 00	1	−20 00	0	0 00
E. by S	−19 30	W. by N	+17 00	−1 15	−18 15	S_7	−17 54	$-S_1$	+ 3 34
ESE	−18 30	WNW	+13 00	−2 45	−15 45	S_6	−14 33	$-S_2$	+ 6 02
SE. by E	−16 45	NW. by W	+ 8 30	−4 08	−12 38	S_5	−10 30	$-S_3$	+ 7 01
SE	−13 45	**NW**	+ 4 30	−4 38	− 9 08	S_4	− 6 27	$-S_4$	+ 6 27
SE. by S	− 9 30	NW. by N	+ 0 30	−4 30	− 5 00	S_3	− 2 47	$-S_5$	+ 4 09
SSE	− 4 30	NNW	− 3 00	−3 45	− 0 45	S_2	− 0 17	$-S_6$	+ 0 42
S. by E	+ 2 30	N. by W	− 6 00	−1 45	+ 4 15	S_1	+ 0 50	$-S_7$	− 4 10
					Sum of + terms =		+ 0 50		+27 55
					Sum of − terms =		−167 22		−98 07
					Divisor 8		−166 32	8	−70 12
						B =	− 20 49	C =	− 8 47

Angles entered in degrees and minutes.
Easterly deviations, mark +
Westerly deviations, mark −

Analysis of deviations of the standard compass on board U. S. S. Dolphin—Continued.

TABLE II.—COMPUTATION OF COEFFICIENTS A, D, E.

9. Upper half of column 5, Table I.	10. Lower half of column 5, Table I.	11. Half sum of columns 9 and 10. Constant deviation.	12. Half sum of cols. 9 and 10, changing sign in col. 10. Quadrantal deviation.	13. Computation of D. Multipliers.	13. Computation of D. Products of column 12 by multipliers.	14. Computation of E. Multipliers.	14. Computation of E. Products of column 12 by multipliers.
° ′	° ′	° ′	° ′		° ′		° ′
0 00	+0 30	+0 15	−0 15	0	0 00	1	−0 15
+2 35	−1 15	+0 40	+1 55	S_2	+0 44	S_6	+1 46
+4 15	−2 45	+0 45	+3 30	S_4	+2 29	S_4	+2 29
+5 38	−4 08	+0 45	+4 53	S_6	+4 31	S_2	+1 52
+5 53	−4 38	+0 38	+5 16	1	+5 16	0	0 00
+5 15	−4 30	+0 23	+4 53	S_6	+4 31	$-S_2$	−1 52
+4 00	−3 45	+0 08	+3 53	S_4	+2 45	$-S_4$	−2 45
+2 28	−1 45	+0 22	+2 07	S_2	+0 49	$-S_6$	−1 58
Sum of + terms =		+3 56	Sum of + terms =		+21 05		+6 07
Sum of − terms =	−		Sum of − terms =		−		−6 50
Divisor 8		+3 56	Divisor 4		+21 05	4 −	0 43
	A =	+0 29.5			D = + 5 16	E =	−0 11

$S_1=0.195$; $S_2=0.383$; $S_3=0.556$; $S_4=0.707$; $S_5=0.831$; $S_6=0.924$; $S_7=0.981$; $S_8=1$; $S_0=0$.

This form is adapted to a computation from observations on the 32 points, but it may be used for 16 or 8 regular points by omitting the intermediate points, and taking as divisors one-half or one-fourth of the divisors here given—that is, for 16 points, the divisor for A, B, and C is to be 4, and for D and E, 2; and for 8 points, the divisor for A, B, and C is 2.

TABLE III.—COMPUTATION OF EXACT COEFFICIENTS $\mathfrak{A}$, $\mathfrak{B}$, $\mathfrak{C}$, $\mathfrak{D}$, $\mathfrak{E}$.

	A	B	C	D	E
	° ′	° ′	° ′	° ′	° ′
	+0 29.5	−20 49	−8 47	+5 16	0 11
Sine	.0086 = $\mathfrak{A}$	−.3554	−.1527	+.0918	−.0032
Versine	* * *	+.0653	+.0117	+.0042	* * *

$\mathfrak{B}$ = sin B [1 + ½ sin D + $\frac{1}{12}$ versin B − ¼ versin C] + ½ sin C sin E

= − .3554 [1 +.0459 + .0054 − .0029] + .1527 × .0016

= − .372

$\mathfrak{C}$ = sin C [1 − ½ sin D + $\frac{1}{12}$ versin C − ¼ versin B] + ½ sin B sin E

= − .1527 [1 − 0.459 + .001 − .0163] + .3554 × .0016

= − .143

$\mathfrak{D}$ = sin D [1 + ⅓ versin D] = .0918 [1 + .0014] = ·092

$\mathfrak{E}$ = sin E − sin A sin D = − .0032 − .0086 × .0918 = − .004

From complete analysis α = 200° 59′.

The diagram shows the curve of deviations of the *Dolphin's* standard compass. The black line represents the total curve; the red line represents the semicircular component; and the green line represents the quadrantal component. This ship was built head N. 20° W. (magnetic), and it will be observed that the points of no semicircular deviation are N. 21° W. and S. 21° E. There are various formulæ for determining the exact coefficients without knowing the approximate coefficients, all of which are to be found in the Admiralty Manual; but there is one to which I wish to call especial attention. If the compass be placed in the

fore and aft midship line of the ship, and due care be exercised in selecting the position, the coefficients $\mathfrak{A}$ and $\mathfrak{E}$ will be so small that they may be neglected and considered zero. Assuming, then, $\mathfrak{A}$ and $\mathfrak{E}$ to be zero, the following formulæ are correct; and $\mathfrak{B}$, $\mathfrak{C}$, and $\mathfrak{D}$ may be deduced from observations for deviation on two adjacent cardinal points and the intermediate quadrantal compass point, thus:

NE. quadrant, $\mathfrak{D} = \dfrac{S_4 \times \sin\delta_4 - \frac{1}{2}(\sin\delta_0 + \sin\delta_8)}{S_4 \times \cos\delta_4 - \frac{1}{2}(\sin\delta_0 - \sin\delta_8)}$ $\quad \mathfrak{B} = (1+\mathfrak{D})\sin\delta_8$, $\quad \mathfrak{C} = (1-\mathfrak{D})\sin\delta_0$

SE. quadrant, $\mathfrak{D} = \dfrac{-S_4 \times \sin\delta_{12} + \frac{1}{2}(\sin\delta_8 + \sin\delta_{16})}{S_4 \times \cos\delta_{12} - \frac{1}{2}(\sin\delta_8 - \sin\delta_{16})}$ $\quad \mathfrak{B} = (1+\mathfrak{D})\sin\delta_8$, $\quad \mathfrak{C} = -(1-\mathfrak{D})\sin\delta_{16}$

SW. quadrant, $\mathfrak{D} = \dfrac{S_4 \times \sin\delta_{20} - \frac{1}{2}(\sin\delta_{16} + \sin\delta_{24})}{S_4 \times \cos\delta_{20} - \frac{1}{2}(\sin\delta_{16} - \sin\delta_{24})}$ $\quad \mathfrak{B} = -(1+\mathfrak{D})\sin\delta_{24}$, $\quad \mathfrak{C} = -(1-\mathfrak{D})\sin\delta_{16}$

NW. quadrant, $\mathfrak{D} = \dfrac{-S_4 \times \sin\delta_{28} + \frac{1}{2}(\sin\delta_{24} + \sin\delta_0)}{S_4 \times \cos\delta_{28} - \frac{1}{2}(\sin\delta_{24} - \sin\delta_0)}$ $\quad \mathfrak{B} = -(1+\mathfrak{D})\sin\delta_{24}$, $\quad \mathfrak{C} = (1-\mathfrak{D})\sin\delta_0$

In these formulæ S_4 is the natural sine of 45°; and δ_0, δ_4, δ_8, etc., are the deviations of the compass on north, NE., east, etc.

Taking the required quantities from the *Dolphin's* table of deviations, and using the formula for the SE. quadrant, we have:

$S_4 = .707 \qquad \delta_8 = -19^\circ 30' \qquad \delta_{12} = -13^\circ 45' \qquad \delta_{16} = +8^\circ 45'$

$\text{Sin}\ \delta_8 = -.334 \qquad \cos\delta_8 = .971 \qquad \sin\delta_{12} = -.238 \qquad \sin\delta_{16} = .152.$

$$\mathfrak{D} = \frac{.707 \times .238 + \frac{1}{2}(-.334 + .152)}{.707 \times .971 - \frac{1}{2}(-.334 - .152)} = \frac{.077}{.929} = .083$$

$\mathfrak{B} = 1.083 \times -.334 = -.362 \qquad \mathfrak{C} = -.917 \times .152 = -.139$

$$a = \tan^{-1}\frac{\mathfrak{C}}{\mathfrak{B}} = 201^\circ 05'$$

Compare these values with those obtained from the analysis of the complete table of deviations.

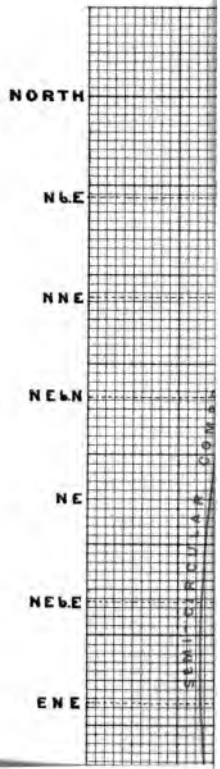
Theoretically $\mathfrak{D}$ always remains constant, and practically it changes very little; so that if it has once been accurately determined, this value can be used in finding new values for $\mathfrak{B}$ and $\mathfrak{C}$ on change of latitude. By observing the deviations on two adjacent cardinal compass points, if $\mathfrak{A}$ and $\mathfrak{E}$ are zero, then,

If the ship is north by compass $\mathfrak{C} = \sin\delta_0\,(1-\mathfrak{D})$

If the ship is east by compass $\mathfrak{B} = \sin\delta_8\,(1+\mathfrak{D})$

If the ship is south by compass $\mathfrak{C} = -\sin\delta_{16}\,(1-\mathfrak{D})$

If the ship is west by compass $\mathfrak{B} = -\sin\delta_{24}\,(1+\mathfrak{D})$


NORTH
NbE
NNE
NEbN
NE
NEbE
ENE
SEMI-CIRCULAR

I give particular weight to these formulæ because with our compensating binnacle we must know the starboard angle; and if at any time it becomes necessary to readjust the compass, I wish to impress upon you the simplicity with which the necessary data for so doing can be obtained.

Before going into the subject of compass compensation, I wish to call your attention to the coefficient which represents the mean directive force of the compass needle, or, in other words, the mean force of the earth and ship to magnetic north.

This mean force is represented by λ.

The semicircular force of the ship, as has already been shown, not only has the effect of producing deviation, but of increasing or decreasing the directive force, according as it acts with or against the horizontal force of the earth. In an entire revolution of the ship, however, this increase of the directive force on one heading is equal to the decrease on the opposite heading; so that as the ship swings round, the mean of the directive forces on any number of equidistant azimuths is unity, that is, the earth's horizontal force.

This is not the case, however, with regard to the effect of the magnetism induced in the soft iron by the earth's horizontal force; for from this the mean force to north is greater or less than unity, depending upon the distribution of the soft iron.

In order to find the horizontal force acting on the compass needle, on any particular heading of the ship, the method adopted is to observe the time required to make a certain number of vibrations with a delicate horizontal magnetic needle; on board ship in the exact position of the compass needle, and on shore in a place free from all local magnetic influences. Then, T being the time of vibrations (10) on shore, and T′ the time of the same number of vibrations on board ship, and calling H the earth's horizontal force, and H′ the horizontal force on board, we have the following ratio:

$$\frac{H'}{H}=\frac{T^2}{T'^2}$$

Calling the earth's horizontal force unity, H′ can be found in terms of that force, and it will represent the horizontal force acting on the needle, in the direction in which the needle points. The force to north, therefore, is $\frac{H'}{H}$ multiplied by the cosine of the deviation. λ being the mean force to north, it is the mean value of $\frac{H'}{H}\cos\delta$ for an entire revolution of the ship. λ may be determined by one observation of force on shore and one on board, if we know the value of the exact coefficients. Thus:

$$\lambda=\frac{H'}{H}\cdot\frac{\cos\delta}{1+\mathfrak{B}\cos\zeta-\mathfrak{C}\sin\zeta+\mathfrak{D}\cos 2\zeta-\mathfrak{E}\sin 2\zeta}$$

In this formula ζ represents the magnetic azimuth of the ship's head, and, as the azimuth is reckoned from 0 to 360°, care must be taken to give the proper signs to the trigonometric functions.

As an example we will take data from the *Atlanta* at the position of the standard compass:

$$\frac{H'}{H}=1.130 \qquad \delta=18^\circ\ 25' \qquad \zeta=214^\circ\ 55' \qquad 2\ \zeta=429^\circ\ 50$$

$$\cos\delta=.949 \qquad \cos\zeta=-.820 \qquad \cos 2\ \zeta=.345$$

$$\sin\zeta=-.572 \qquad \sin 2\ \zeta=.939$$

$$\mathfrak{B}=-.220\,;\ \mathfrak{C}=-.126\,;\ \mathfrak{D}=.126\,;\ \mathfrak{E}=.019$$

$$\lambda=\frac{1.130\times .949}{1+(-.220\times -.820)-(-.126\times -.572)+(.126\times .345)-(.019\times .939)}$$

$$\lambda=\frac{1.072}{1.134}=.946$$

It is now generally recognized that the compensation of the compasses on board an iron or steel vessel is a necessity, and especially is this the case with regard to the steering compass, for with this there is no choice of position. With regard to the standard compass, however, it is often possible to select such a favorable position with reference to the ship's magnetism that the deviations are small and compensation is unnecessary.

Where there is a large semicircular force acting on the compass, not only are the deviations excessive, but the loss of directive force on certain headings is so great that the compass becomes practically useless. The mechanical correction of the semicircular deviation, by means of magnets properly disposed, has the effect, not only of reducing this deviation, but of equalizing the directive forces on the different headings.

The semicircular deviation can be compensated by the use of two magnets; one to compensate the disturbance due to the fore-and-aft component of the ship's force, or B; and the other to compensate the disturbance due to the athwartship component, or C.

To correct B, bring the ship's head to magnetic east or west and place the magnet parallel to the fore-and-aft line of the ship and parallel to the deck, with the center of the magnet in the vertical plane passing through the center of the compass card, and, having due regard to the proper direction of the poles, move it nearer or farther away until the compass shows east or west. If +B is to be compensated the north pole of the magnet must be forward; if −B, then the south pole must be forward.

To correct C, the ship's head must be brought to magnetic north or south and a magnet placed athwartships perpendicular to the fore-and-aft line and parallel to the deck, with its center in the vertical plane passing through the center of the compass and at such a distance that

the compass will show north or south. If +C is to be compensated the north pole of the magnet must be to starboard; if —C, then the south pole must be to starboard. The whole of the semicircular deviation can be compensated by one magnet or set of magnets placed directly under the center of the compass, the direction being that of the ship's starboard angle.

The quadrantal deviation is corrected by placing equal masses of soft iron on each side of the compass on a level with the needles. If D be positive, which is almost universally the case, these masses of iron should be athwartships, thus producing a —D, and at such a distance from the center of the compass as to reduce the quadrantal deviation to zero. The introduction of the quadrantal correctors has the effect of increasing the mean directive force of the needles, as can be seen by referring to the diagram representing the soft iron rods $+e$.

Such being the general plan of compensating the semicircular and quadrantal errors of the compass, there are various binnacles constructed with devices for carrying these plans into execution. The binnacle designed in the Bureau of Navigation, and intended for use on board the new cruisers, may be briefly described as follows:

The means for correcting the semicircular deviation consists in a number of bar magnets placed in a metal ring immediately below the compass, the center of the ring and the center of the compass being in the same vertical line when the ship is upright. The ring can be moved up and down on a vertical tube, and in azimuth in the frame which supports the ring. A scale in inches on the tube denotes the distance of the magnets from the plane of the compass needles, and the graduation on the ring denotes the angle in which the magnets are placed with reference to the ship's head.

A vertical magnet, for correcting the heeling error, is carried in the vertical tube; and, by a simple device, it can be clamped at any required distance from the compass needles.

For correcting the quadrantal deviation, there are two cast-iron spheres, mounted on the arms of a ring that encircles the cylinder containing the compass. This ring can be moved in azimuth, and the spheres can be moved to and from the compass. Their centers are in the plane of the needles, and their distance from the center of the compass is shown by scales on the supporting arms.

In order to effect the compensation of a compass placed in this binnacle, the magnets and spheres must first be moved to such a distance that their influence will not be felt. Now swing the ship for a table of deviations with the ship upright. Analyze this table, and determine the semicircular and quadrantal components, the magnetic coefficients, and the starboard angle. Place the ship's head on magnetic north (or any other cardinal point); lower the metal ring to the bottom of the binnacle, and, if the deviations are large, place all the magnets in the ring with the north poles towards the bow of the ship, and then turn the

ring in azimuth until the north poles of the magnets point in the direction of the starboard angle. Now raise the magnets until the compass shows north; bring the ship's head to magnetic NE. (or any other quadrantal point); secure the cast-iron spheres to the arms of the supporting ring; and, if E be small, the ring can be clamped so that the spheres will be directly athwartships; and move the spheres in or out until the compass shows NE.

If E amounts to two or three degrees, this amount can be left uncorrected by the magnets at north. Find the angle of which the natural tangent is $\frac{E}{D}$ and move the ring carrying the spheres through one-half this angle, and then correct the whole error on NE.

If E is positive, the starboard sphere should be moved towards the stern; if negative, it should be moved towards the bow.

The compass should now be practically free from horizontal error, but the ship should always be swung for a table of residual deviations.

On board the *Atlanta*, at Newport, after obtaining a table of deviation for her steering compass and analyzing it, the work of effecting the compensation did not occupy more than fifteen minutes. To show that this was done effectually, I call your attention to the diagram of the curve and to the table of errors before and after compensation.

It is always better to have a complete table of deviations of a compass before correcting it, but it is not absolutely necessary.

Deviation table and magnetic coefficients of the Atlanta's steering compass before adjustment, at Newport, R. I.

Ship's head by compass.	Deviation.	Ship's head by compass.	Deviation.	Magnetic coefficients.
	° ′		° ′	
North	−18 00	South	+18 30	A = +0° 21′.
N. by E.	−20 30	S. by W	+32 15	$\mathfrak{A}$ = +.006.
NNE	−23 45	SSW	+43 00	B = −36° 10′.
NE. by N.	−25 00	SW. by S	+48 40	$\mathfrak{B}$ = −.654.
NE	−26 20	SW	+50 00	C = −16° 11′.
NE. by E.	−27 45	SW. by W	+48 15	$\mathfrak{C}$ = −.239.
ENE	−29 15	WSW	+44 50	D = +11° 48′.
E. by N.	−30 40	W. by S	+40 00	$\mathfrak{D}$ = +.206.
East	−32 00	West	+33 45	E = −0° 16′.
E. by S.	−33 10	W. by N.	+26 50	$\mathfrak{E}$ = −.006.
ESE	−33 10	WNW	+19 20	
SE. by E.	−31 45	NW. by W	+12 45	$\alpha = \tan^{-1}\frac{\mathfrak{C}}{\mathfrak{B}} = 200° 04′$.
SE.	−28 45	NW	+ 6 00	
SE. by S.	−23 30	NW. by N.	0 00	
SSE	−12 50	NNW	− 6 40	
S. by E.	+ 3 00	N. by W.	−13 00	

Atlanta's steering compass.

Ship's head by compass.	Deviations before compensations.	Residual deviations after compensation.	Ship's head by compass.	Deviations before compensations.	Residual deviations after compensation.
	° ′	° ′		° ′	° ′
North	−18 00	− 1 15	South	+18 30	0 0
NNE	−23 45	+ 1 30	SSW	+43 00	−1 00
NE	−26 20	+ 0 45	SW	+50 00	0 0
ENE	−29 15	+ 1 00	WSW	+44 50	+0 30
East	−32 00	+ 1 00	West	+33 45	+0 15
ESE	−33 10	0 0	WNW	+19 20	−1 00
SE	−28 45	0 0	NW	+ 6 00	−1 00
SSE	−12 50	+ 1 00	NNW	− 6 40	−1 00

With this compensating binnacle we must know the starboard angle, and it matters not how we obtain it. To illustrate that it was only necessary to observe the deviations on three points—that is, east, southeast, and south—in order to obtain the starboard angle, in the case of the *Atlanta*, I beg you to compare the angle as obtained by this method with that obtained by the analysis of the complete table:

$$\delta_8=-32^\circ \quad \delta_{12}=-28^\circ 45' \quad \delta_{16}=+18^\circ\, 30' \quad S_4=.707 \quad \text{Sin } \delta_8=-.530$$

$$\text{Sin } \delta_{12}=-.481 \quad \text{Cos } \delta_{12}=.877 \quad \text{Sin } \delta_{16}=.317$$

Using the formula for the southeast quadrant, and substituting these values, we have—

$$\mathfrak{D}=\frac{.707\times.481+\frac{1}{2}\,(-.530+.317)}{.707\times.877-\frac{1}{2}\,(-.530-.317)}=\frac{.234}{1.043}=.224$$

$$\mathfrak{B}=-.53\times1.224=-.649 \qquad \mathfrak{C}=-.317\times.776=-.246$$

$$a=\tan^{-1}\frac{\mathfrak{C}}{\mathfrak{B}}=200^\circ\, 46'$$

From analysis of complete table $a=200^\circ\ 04'$. If the quadrantal error has once been accurately compensated, this compensation should remain good in any part of the world, so that, if it becomes necessary to readjust the compass for semicircular error, all that is required is to remove the correcting magnets, ascertain the compass errors on the two cardinal points nearest the course of the ship, and obtain a new value for the starboard angle. Suppose the ship's course to be between north and east; then the sine of the deviation at east will be the coefficient $\mathfrak{B}$, and the sine of the deviation at north will be the coefficient $\mathfrak{C}$. Place the magnets in the new starboard angle found from these coefficients; bring the ship's head to magnetic north or east, as is most convenient, and raise the magnets until the compass indicates the correct heading. If there be any doubt as to the accuracy of the quadrantal correction, remove the spheres as well as the magnets and obtain the values of the coefficients on three points, as illustrated above.

All the semicircular deviation can be compensated by magnets, and if the ship remain in the same magnetic latitude the compensation will remain good, providing the magnets retain their power and the magnetism of the ship itself does not change. If, however, there be any of the semicircular force due to vertical induction in soft iron the compensation will not remain perfect upon a change of latitude. It becomes important, therefore, to be able to separate that part of the semicircular force which is due to induction in vertical soft iron from the part due to permanent magnetism. Generally the vertical iron is symmetrically distributed with respect to the longitudinal plan of the ship, and, therefore, the coefficient $\mathfrak{C}$ depends almost entirely upon the disturbing force of the permanent magnetism. This is not the case, however, with , for if there are large masses of vertical iron, either forward or abaft the compass, then a large part of $\mathfrak{B}$ may be caused by vertical induction in this iron.

In the theory of the deviation of the compass we have the expression $\mathfrak{B}=\frac{P}{\lambda H}+\frac{c}{\lambda}\tan\theta$; in which $\frac{P}{\lambda H}$ represents the part of $\mathfrak{B}$ due to permanent magnetism, and $\frac{c}{\lambda}\tan\theta$ represents the part due to vertical induction in soft iron. It will be seen that the former varies inversely as H (the horizontal force of the earth), and the latter as the tangent of the dip. After the magnetism of the ship has settled down to its permanent condition, $\mathfrak{B}$ can be separated into its two parts by determining its value in two places considerably apart in latitude, providing we know the earth's horizontal force and the dip at these two places. We will take data from the *Ranger* to illustrate this.

At Acapulco, Mexico, $\mathfrak{B}=-.2683$.
$H=.3466$, Dip$=40^\circ\ 08'$, tan dip$=.8431$.
At San Francisco, $\mathfrak{B}=-.3274$.
$H=.2550$, Dip$=62^\circ\ 25'$, tan dip$=1.913$.

Substituting these values in the above formula, we have

$$\frac{P}{\lambda}+.8431\times.3466\ \frac{c}{\lambda}=-.2683\times.3466$$

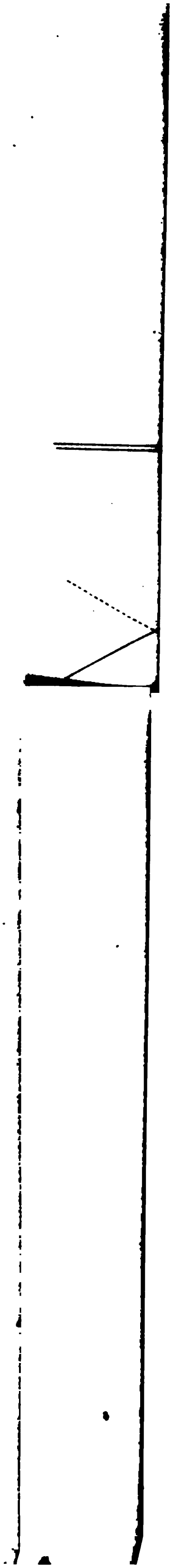
$$\frac{P}{\lambda}+.2550\times1.913\ \frac{c}{\lambda}=-.3274\times.2550$$

$$\text{whence } \frac{c}{\lambda}=.0486 \text{ and } \frac{P}{\lambda}=-.1072 \text{ or } 2^\circ.8 \text{ and} -6^\circ.15$$

Using these values with the horizontal force and tan . of dip at Acapulco, we have:

$$B=\frac{-6^\circ.15}{.3466}+2^\circ.8\times.8431=-17^\circ\ 42'+2^\circ\ 22'=-15^\circ\ 20'$$

Knowing thus what part of B is due to vertical soft iron, this part can be compensated by a rod of vertical iron, or Flinder's bar, and the remainder corrected by magnets. If this be done the errors of a *compensated* compass need be very small in any part of the world.



In adjusting the *Atlanta's* steering compass all the semicircular error was corrected by magnets, as she would not greatly change her latitude during the trial trip. Before she starts on a regular cruise, however, I propose to correct about half the error on east by a Flinder's bar, as I estimate that at least this amount is due to vertical induction in soft iron.

The discussion of the errors of the standard compasses on board the *Atlanta* and *Boston* bring to light some instructive facts. During the passage of the latter vessel from Chester to New York I was able to obtain a table of deviations off Cape May:

Deviation table and magnetic coefficients of the Atlanta's standard compass at Newport, R. I.

Ship's head by compass.	Deviation.	Ship's head by compass.	Deviation.	Magnetic coefficients.
	° '		° '	
North	− 6 15	South	+10 45	A = +0° 46'.
N. by E	− 6 00	S. by W	+16 00	$\mathfrak{A}$ = .013.
NNE	− 5 30	SSW	+19 40	B = −11° 54'.
NE. by N	− 5 30	SW. by S	+21 15	$\mathfrak{B}$ = −.220.
NE	− 6 00	SW	+21 45	C = −7° 40'.
NE. by E	− 7 00	SW. by W	+20 15	$\mathfrak{C}$ = −.126.
ENE	− 8 30	WSW	+17 45	D = +7° 14'.
E. by N	−10 00	W. by S	+14 30	$\mathfrak{D}$ = .126.
East	−11 15	West	+11 00	E = +1° 04'.
E. by S	−12 15	W. by N	+ 7 25	$\mathfrak{E}$ = .017.
ESE	−12 50	WNW	+ 4 00	
SE. by E	−12 20	NW. by W	+ 0 30	$\alpha = \tan^{-1}\frac{\mathfrak{C}}{\mathfrak{B}} = 209° 48'$.
SE	−11 00	NW	− 3 00	
SE. by S	− 7 45	NW. by N	− 5 00	
SSE	− 1 50	NNW	− 6 00	
S. by E	+ 4 15	N. by W	− 6 30	

Deviation table and magnetic coefficients of the Boston's standard compass, off Cape May.

Ship's head by compass.	Deviation.	Ship's head by compass.	Deviation.	Magnetic coefficients.
	° '		° '	
North	− 4 15	South	+ 8 15	A = +0° 23'.
N. by E	− 3 05	S. by W	+12 30	$\mathfrak{A}$ = .007.
NNE	− 2 30	SSW	+15 30	B = −9° 00'.
NE. by N	− 2 45	SW. by S	+17 00	$\mathfrak{B}$ = −.166.
NE	− 3 40	SW	+17 00	C = −5° 36'.
NE. by E	− 5 05	SW. by W	+15 00	$\mathfrak{C}$ = −.095.
ENE	− 7 00	WSW	+12 50	D = +6° 15'.
E. by N	− 8 30	W. by S	+10 10	$\mathfrak{D}$ = .109.
East	− 9 30	West	+ 7 30	E = +1° 39'.
E. by S	−10 20	W. by N	+ 4 40	$\mathfrak{E}$ = +.028.
ESE	−11 00	WNW	+ 2 00	
SE. by E	−10 40	NW. by W	− 1 00	$\alpha = \tan^{-1}\frac{\mathfrak{C}}{\mathfrak{B}} = 209° 47'$.
SE	− 9 50	NW	− 2 50	
SE. by S	− 7 00	NW. by N	− 4 00	
SSE	− 1 30	NNW	− 5 00	
S. by E	+ 4 30	N. by W	− 5 00	

The standard compasses of these ships were placed on temporary platforms on the quarter deck, in exactly similar positions. You will observe that the curves are identical, except that the errors of the *Atlanta's* compass are slightly greater, which is perfectly accounted for by the difference in the earth's horizontal force and magnetic dip in the two places where the respective observations were made. This is rather curious, when we take into consideration the fact that while the *Boston* has been lying in the direction in which she was built for the past six months, during which time she has had all her dock trials, and that the *Atlanta* had similar trials alongside the dock at the New York navy-yard in almost an opposite direction, after the trials at the Morgan Iron Works, where she was heading about NW. by W. The amount and direction of the polar force of these two ships being practically the same upon the first sea trial, it would seem to indicate that the magnetism induced in these ships during the process of construction is nearly, if not entirely, of a permanent nature, and that it will never be subject to great change. This is a most desirable condition, and, if true, it is probably due to the fact that the ships are constructed of steel of very excellent quality.

Assuming the polar force of the two ships to be the same in amount and direction at the position of the standard compass, we can estimate very closely the amount of $\mathfrak{B}$ due to permanent magnetism and that due to vertical induction in soft iron. Using the value of $\mathfrak{B}$ on board the *Atlanta* at Newport, and that on board the *Boston* at Cape May; and knowing the earth's horizontal force and dip at each place, we have:

At Cape May $\mathfrak{B}=-.166$, $H=4.283$, $\tan\theta=2.984$.

At Newport $\mathfrak{B}=-.220$, $H=3.364$, $\tan\theta=3.264$.

Substituting these values in the formula already given,

$$-.166\times 4.283=\frac{P}{\lambda}+4.283\times 2.984\frac{c}{\lambda}$$
$$-.220\times 3.364=\frac{P}{\lambda}+3.364\times 3.264\frac{c}{\lambda}$$

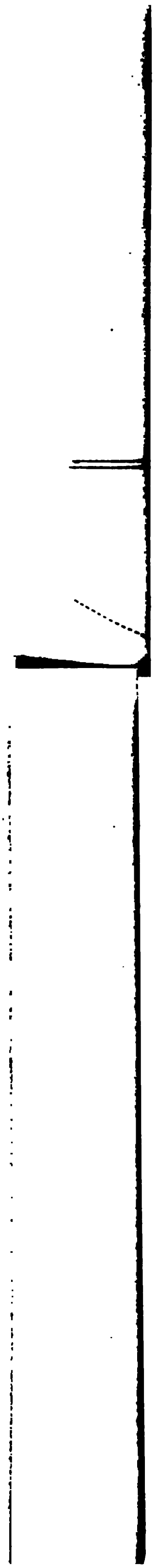
Whence $\frac{c}{\lambda}=.016$ and $\frac{P}{\lambda}=-.917$.

At Newport then:

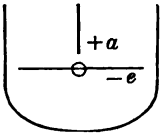
$$\mathfrak{B}=-\frac{.917}{3.364}+.016\times 3.264=-.2723+.052=-.220.$$

From this it will be seen that almost all the semicircular force in the position of the standard compass is due to permanent magnetism.

With reference to the quadrantal deviation, the rather large value of D (7° 15′) is readily accounted for. D is almost universally positive, and ordinarily it is caused by the excess of horizontal induction in athwartship iron over horizontal induction in fore-and-aft iron; the former caus-



ing a positive value of D and the latter a negative value. The following calculation will show, however, that in the case of the *Atlanta* both forces produce a positive value and that the horizontal iron presents the type



$$\mathfrak{D} = \frac{1}{\lambda} \cdot \frac{a - e}{2} \text{ and } \lambda = 1 + \frac{a + e}{2}$$

whence $a = \lambda\,(1 + \mathfrak{D}) - 1$ = magnetic induction in fore and-aft iron and $e = \lambda\,(1 - \mathfrak{D}) - 1$ = magnetic induction in transverse iron.

$$\lambda = .946 \text{ and } \mathfrak{D} = .126$$

hence $a = .065$ and $e = -.173$.

$$\mathfrak{D} = .034 + .092 \text{ and } D = +\,1^{\circ}\,58' + 5^{\circ}\,17' = 7^{\circ}\,15'$$

The positive value of a is probably due to the superstructure deck, which is nearly on a level with the compass and but a short distance from it, and the compass was elevated nearly 12 feet above the quarter deck.

In swinging an iron ship for a table of deviations, it is important to retain the ship on each heading for a sufficient time to allow the magnetism induced in the soft iron to be that which is due to each particular heading. Were the iron perfectly soft this change of magnetism would take place at once; but in practice it is found that the iron is slow in receiving or losing its whole amount of induced magnetism. The error arising from this slowness of the iron in changing its amount of magnetism is known as the Gaussin error; and it will produce a temporary + A and + E if the ship is swung to the left and — A and — E if swung to the right. The most reliable table of deviations would be obtained by swinging both ways and taking the mean of the errors found.

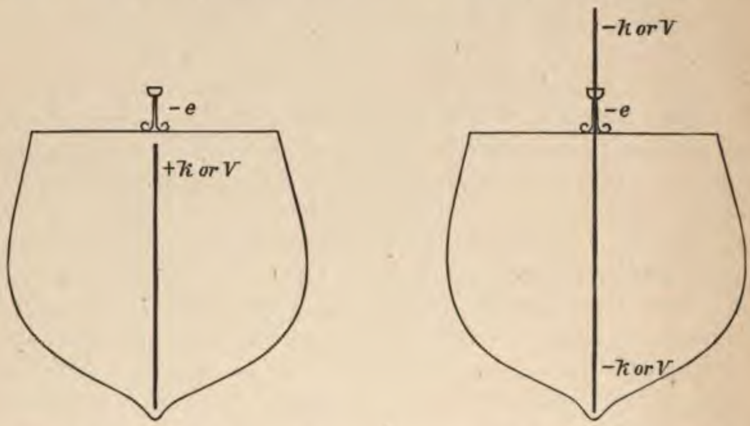
When an iron ship has been in one direction for any considerable length of time, either alongside the dock or at sea, it acquires an amount of temporary magnetism by the earth's induction known as *retained* magnetism. This magnetism is not of a permanent character, for it is lost in time by altering the direction of the ship's head. The effect of retained magnetism is that when a ship has been kept on one course for a long time a deviation towards that course is produced upon a change of heading. Thus, suppose a ship had been steering east for a week or more and then changed her course to north. The retained magnetism would cause a deviation of the needles towards the east, and when the compass showed north the magnetic heading might be N. by E. The effect of retained magnetism must be taken into account upon

changing a course that has been maintained for any considerable time, for it cannot be considered in the adjustment of the compass. Before a compass is adjusted the ship should be allowed to swing about on different headings, either at anchor or under way, if she has been for any length of time alongside the dock, in order to get rid of this retained magnetism.

Thus far only those compass disturbances have been considered which have their effect while the ship is upright. When the ship heels, other forces come into play, and these must now be considered.

While the ship is upright the vertical component of the ship's subpermanent magnetism has no effect in producing deviation; but the moment the ship heels, this becomes a disturbing semicircular force. The induction in vertical soft iron, either above or below the compass, has the same effect. Besides these forces, we have the effect of vertical induction in iron that was horizontal while the ship was upright, but which has a vertical component when the ship heels, and this also becomes a disturbing semicircular force.

By referring to the following diagrams and explanation, taken from Evans' Manual, the causes of the heeling error will become apparent:



"The effect of every usual arrangement of soft and hard iron in producing the principal part of the heeling error, or changes in $\mathfrak{C}$, may be represented by one or other of the following types: where —*e* represents, as before, the transverse soft iron, which will evidently, as the ship heels over, produce a force to windward on the north end of the needle. If the rods $+k$ or V, and $-k$ or V, represent soft iron and permanent magnetism combined, then $+k$ or V gives a force acting downwards on the north end of the compass needle, which, as the ship heels over, becomes a force to windward; and $-k$ or V, a force acting upwards, which, as the ship heels over, becomes a force to leeward."

If the compass be placed near that end of the ship that was south in building, there will be a strong downward force and a consequent de-